UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

SOIL REPORT No. 51

FULTON COUNTY SOILS

By R. S. SMITH, E. E. DeTURK, F. C. BAUER and L. H. SMITH

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The Soil Survey of Illinois was organized under the general supervision of Professor Cyril G. Hopkins, with Professor Jeremiah G. Mosier directly in charge of soil classification and mapping. After working in association on this undertaking for eighteen years, Professor Hopkins died and Professor Mosier followed two years later. The work of these two men enters so intimately into the whole project of the Illinois Soil Survey that it is impossible to disassociate their names from the individual county reports. Therefore recognition is hereby accorded Professors Hopkins and Mosier for their contribution to the work resulting in this publication.

[1] Engaged in Soils Extension as well as in Soil Experiment Fields.

INTRODUCTORY NOTE

IT IS A MATTER of common observation that soils vary tremendously in their productive power, depending upon their physical condition, their chemical composition, and their biological activities. For any comprehensive plan of soil improvement looking toward the permanent maintenance of our agricultural lands, a definite knowledge of the various existing kinds or types of soil is a first essential. It is the purpose of a soil survey to classify the various kinds of soil of a given area in such a manner as to permit definite characterization for description and for mapping. With the information that such a survey affords, every farmer or landowner of the surveyed area has at hand the basis for a rational system of improvement of his land. At the same time the Experiment Station is furnished an inventory of the soils of the state, upon which intelligently to base plans for those fundamental investigations so necessary for solving the problems of practical soil improvement.

This county soil report is one of a series reporting the results of the soil survey which, when completed, will cover the state of Illinois. Each county report is intended to be as nearly complete in itself as it is practicable to make it, even at the expense of some repetition. There is presented in the form of an Appendix a general discussion of the important principles of soil management, in order to help the farmer and landowner to understand the significance of the data furnished by the soil survey and to make intelligent application of the same in the maintenance and improvement of the land. In many cases it will be of advantage to study the Appendix in advance of the soil report proper.

While the authors must assume the responsibility for the presentation of this report, it should be understood that the material for the report represents the contribution of a considerable number of the present and former members of the Agronomy Department working in their respective lines of soil mapping, soil analysis, and experiment field investigation.

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APPENDIX

FULTON COUNTY SOILS

By R. S. SMITH, E. E. DeTURK, F. C. BAUER and L. H. SMITH[1]

GEOGRAPHICAL FEATURES OF FULTON COUNTY

FULTON COUNTY is located in the west-central part of Illinois on the banks of Illinois river. Spoon river, made famous by Master's "Spoon River Anthology," flows thru the county from north to south. It is a large county, extending 36 miles north and south and 30 miles east and west in its widest place. It occupies an area of 868.76 square miles, or 556,006 acres.

The better agricultural portions of the county are well provided with rail transportation, and there are well-distributed state concrete highways. Many of the rougher portions of the county are rather inaccessible because of the steepness of the slopes and the poor condition of the roads, particularly in the spring.

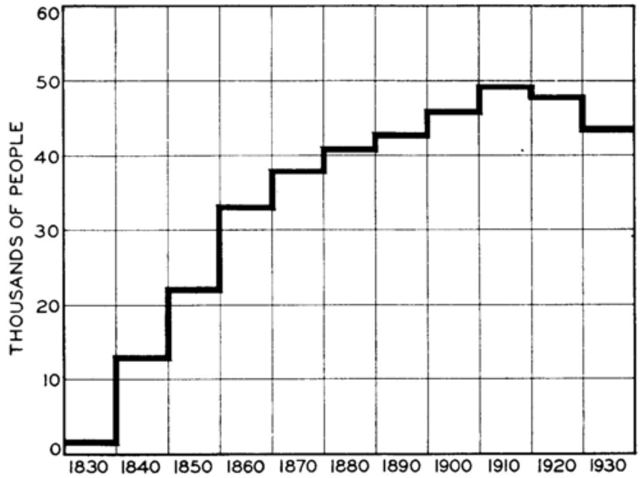

FIG. 1.—GROWTH IN POPULATION IN FULTON COUNTY
Population reached its maximum in the first decade of the present century, since which time it has declined.

The first white settler, John Everland, came from Kentucky and settled in what is now Fulton county in the spring of 1820. The county was organized in 1823 and the town of Canton was laid out in 1825 and incorporated in 1837. It is of interest to note that this county was named in honor of Robert Fulton, generally credited with being the inventor of the steamboat. Railroad construction started at an early date, the first railroad to touch the county, and known at that time as the Northern Cross, was completed between Quincy and Galesburg in 1855. Census figures show a steady increase in population from 1830 to 1910, and then a decline thereafter (Fig. 1).

[1] R. S. SMITH, Chief in Soil Physics, in charge of identification and mapping of soil types; E. E. DETURK, Chief in Soil Technology, in charge of soil analysis of the Soil Survey; F. C. BAUER, Chief in Soil Experiment Fields; L. H. SMITH, Chief, in Charge of Publications of the Soil Survey.

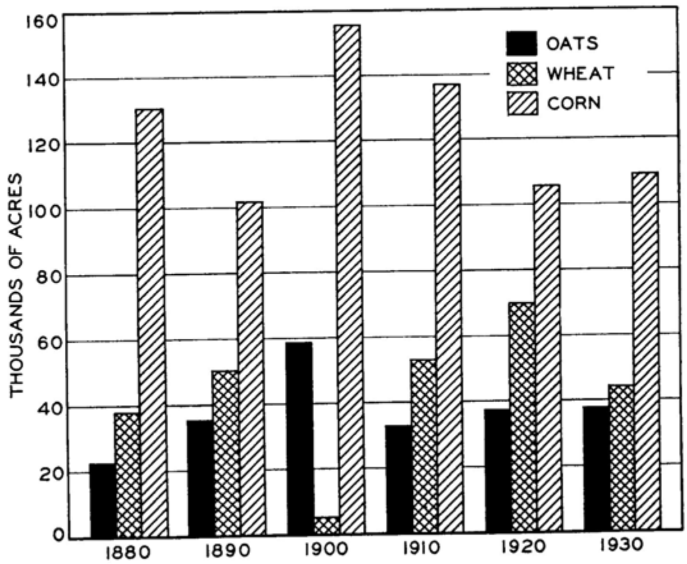

FIG. 2.—ACREAGE OF CORN, OATS, AND WHEAT IN FULTON COUNTY

The diagram shows the relative acreage devoted to the three principal grain crops at periodic intervals since 1880. (Figures from U. S. Census)

History of Agricultural Production

The early settlers found the prairies in Fulton county better drained and therefore more easily farmed than some other regions of the state. Flat areas, which could not be used until underdrainage was installed, occupied but a small portion of the total area of the county. U. S. census reports, (Fig. 2) show the trend in acreages of corn, oats, and wheat from 1880 to 1930 inclusive. It is

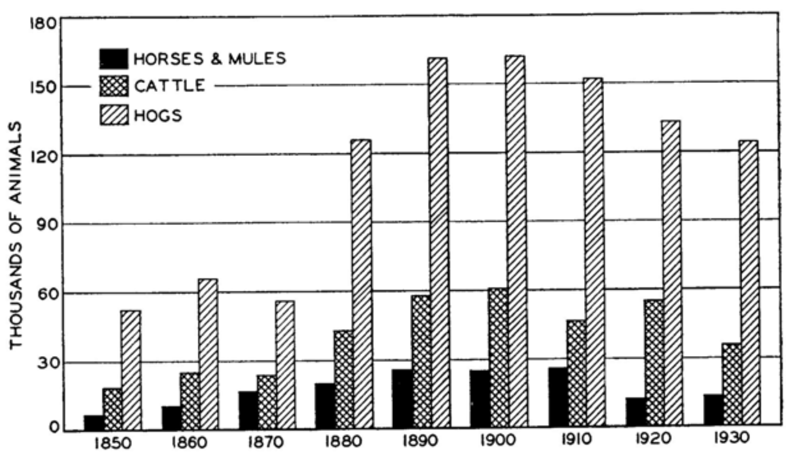

FIG. 3.—NUMBERS OF HORSES AND MULES, CATTLE, AND HOGS IN FULTON COUNTY

The diagram shows the relative numbers of the principal classes of livestock at periodic intervals since 1850. (Figures from U. S. Census)

interesting to note that the production of these crops was large as early as 1880, and that corn and oats reached maximum production in 1900, while the greatest wheat acreage was attained in 1920.

The Illinois Cooperative Crop Reporting Service reports an average yield for Fulton county of 37 bushels of corn an acre, 18.8 bushels of winter wheat, 34.1 bushels of oats, and 1.55 tons of hay for the ten-year period 1921 to 1930. A six-year average for spring wheat shows 15.9 bushels an acre.

Fruit and vegetable crops are of little commercial importance in Fulton county.

Fig. 3 shows the trend in livestock production since 1880. It is of interest to note that the number of horses and mules reached a maximum in 1910, and that since that time there has been a decline of slightly more than 47 percent. Hogs and cattle reached their maximum number in 1900, since which time hogs have declined about 17 percent and cattle about 41 percent.

Climate

The climate of Fulton county is characterized by a wide range between the extreme temperatures of summer and winter, by an abundant rainfall, and by considerable variation from year to year in length of growing season. The highest temperature recorded at Rushville from 1902 to 1929, twenty-eight years, was 107° in 1918; the lowest was 22° below zero in 1924. The mean summer temperature was 74° and the winter 28.7°.

The average date of the last killing frost in the spring during the 1902-1929 period was April 23; and the earliest in the fall, October 16, giving an average growing season of 176 days. The shortest growing season recorded was 138 days in 1925 and the longest 206 days in 1903 and 1921. The earliest killing frost in fall occurred September 26, 1928.

The average yearly rainfall for the thirteen-year period 1917-1929 was 35.95 inches; this includes the water melted from an average yearly snowfall of 21.28 inches. The distribution of rainfall during the growing season is fairly good, tho nearly every year there are one or more rainless periods of sufficient length to be somewhat harmful to growing crops. During the thirteen-year period 1917-1929 there were four years in which there was a rainless period of 30 days or more during the growing season. Ten rainless periods of 20 to 30 days duration occurred during this same period. There are a number of factors, however, other than amount and distribution of rainfall, that are important in producing drouth conditions. Among these are the character of the rainfall preceding rainless periods and the evaporation during the rainless periods. Then there are also to be considered the crop's reaction to drouth conditions, its stage of growth, and whether it is a resistant crop or one easily affected by drouth.

Physiography and Drainage

Fulton county contains a large proportion of rough land, 30 percent of the total area of the county being classified as eroded. The narrow, flat, or tabular divides are an interesting physiographic feature of the county. No glacial

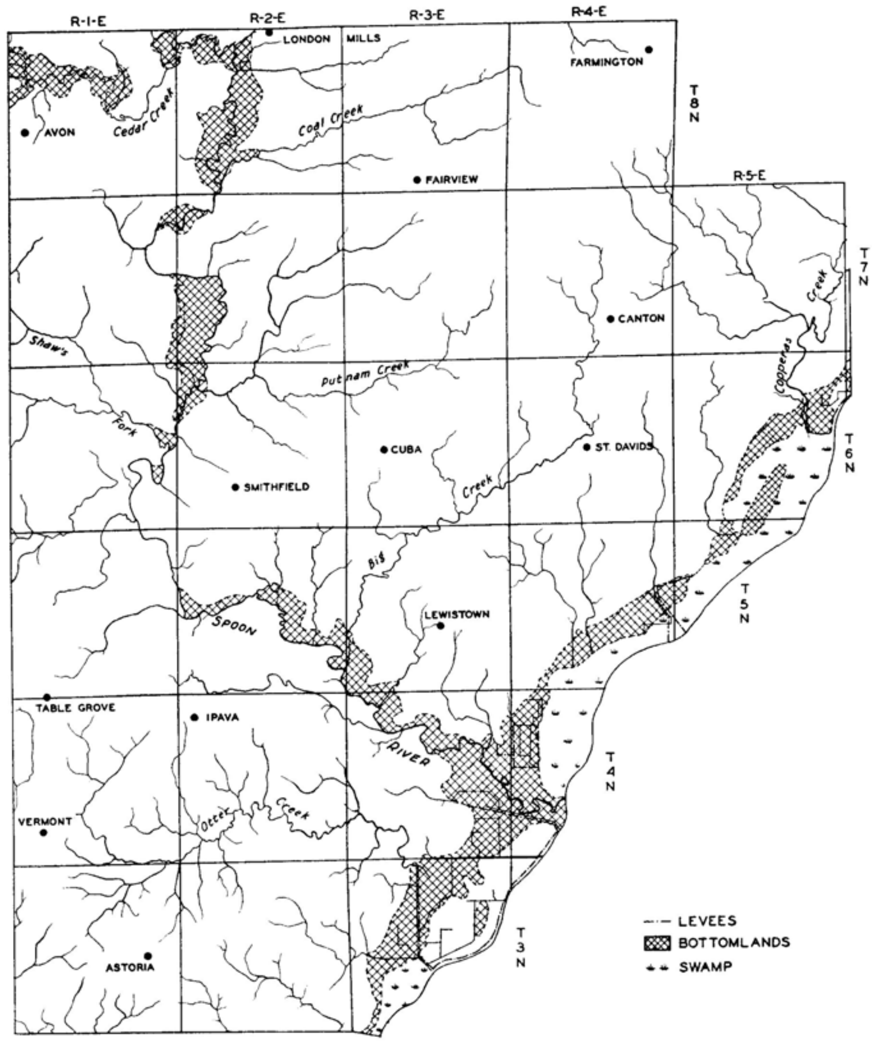

FIG. 4.—DRAINAGE MAP OF FULTON COUNTY, SHOWING STREAM COURSES, BOTTOM LANDS, SWAMP, AND LEVEES

moraines of any consequence occur in the county, the present topography being the result of erosion rather than deposition. Most of the county was flat prior to the cutting back of Otter creek, Spoon river and its tributaries, and the smaller streams which empty directly into Illinois river. The bottom lands along the streams are narrow with the exception of the Spoon and Illinois bottoms, and the slopes leading from the bottom lands to the uplands are generally steep and largely unsuited to general farming.

Fulton county is well drained, as shown by the accompanying drainage map. (Fig. 4). The streams have cut back until only narrow remnants of the original flat table-land remain. Some of these narrow divides are occupied in part by soils having impervious subsoils. Areas underlain by an impervious subsoil are shown on the soil map, and it will be noted that they are all small in extent.

These areas are poorly drained, but their small size makes it possible to remove excess water by means of furrows and open ditches. The wider divides are occupied by dark-colored soils which are the remnants of a once much more extensive prairie soil. The flatter portions of the dark-colored soil regions require tile drainage, particularly those lying northwest of Canton.

FORMATION OF FULTON COUNTY SOILS

Origin of Soil Material

The most important period in the geological history of the county, from the standpoint of soil formation, was the Glacial Epoch, for it was during and following this period that the material of which the present soils were formed was deposited, and it was thru glacial action and subsequent erosion that the present topography was largely determined.

At the time of the glaciers the climate was colder than at present. Vast accumulations of snow and ice took place in regions to the north, and from these centers of accumulation immense masses of snow and ice pushed outward, advancing chiefly southward until a place was reached where the climate was warm enough to melt the ice as rapidly as it advanced. In moving across the country from the far north, the ice gathered up all sorts and sizes of materials, including clay, sand, gravel, boulders, and even immense masses of rock. Some of these materials were carried hundreds of miles and rubbed against surface rocks and against each other until largely ground into powder Under the enormous pressure of the ice, hills were leveled off and valleys filled in; thus greatly changing the features of the surface over which the ice sheet passed. With rapid melting, the glaciers receded, leaving a mixture of mineral materials, known as till or drift, scattered over the areas which they had occupied.

The upland soils of Fulton county were derived from loess, a wind-blown glacial material which was deposited on top of the drift sheet following the retreat of the glacier. The loess in this county probably came chiefly from the Illinois river bottom. It is thinnest in the northwestern corner of the county, having a depth of about five feet in that section. It is indeed so deep all over the county that even underlying glacial drift, deposited by the last ice sheet, known as the Illinoian, has no direct effect on the character of the soils.

Loess is an excellent soil-forming material. Its texture, or size of particles, is ideal for ease of tillage, it is free from stones, and it is well supplied with all the elements of plant food. In a region like Fulton county, where leaching has not progressed very far, the soils still contain a large proportion of the elements of plant food originally present in the loess.

Soil Development

The story of the development of the soils in Fulton county from the original raw materials is an interesting one but it cannot be told in full in the space available in this report. It is likely that more than one glacier passed over the region now within the boundaries of Fulton county. Altho they may have had no direct effect, indirectly the glaciers had a strong influence on the character

of the soils as we now find them in that they left a flat-lying plain upon which the loess was deposited. Slope, or the lay or the land, is an important factor in determining soil character, as will appear later in the discussion.

Upon the melting back, or retreat, of the Illinoian glacier, the forces of weathering which develop soils—freezing and thawing, wetting and drying, oxidation and solution—began to act. The lower forms of plant life began to grow, and in time the material left by the ice sheet gradually took on some of the characteristics of soils. As time went on the higher forms of vegetation gained a foothold and vegetative growth became luxuriant. On the slopes bordering the streams timber began to grow, and a grass vegetation took hold on the flat uplands.

Sufficient time clapsed between the retreat of the Illinoian ice sheet and the deposition of the loess which now covers the county to permit the development of a mature soil. This soil, formed from the Illinoian drift, is now a buried soil and may be seen in cuts that are deep enough to penetrate thru the loess blanket and into the old drift.

With the deposit of the thick blanket of loess a new cycle of soil formation started. The loess, sometimes spoken of as "rock flour," yielded to the forces of weathering more readily than did the drift because the particles were small and thus more rapidly attacked than were the pebbles and boulders which make up such a large part of the drift. The influence which the glacial drift, even tho buried, had on the character of the soils developed from the loess must be mentioned a little more fully.

The kind of soil formed from any given material depends on the environment under which it is developed. The permeability of the underlying material and the topography of the region are important factors in determining soil environment in that within any given climatic region they strongly influence what might be called "soil climate." The movement of water, thru a deposit of soil material such as loess or from the surface of the soil as run-off, is free or is interrupted according to the permeability of the underlying material and the slope of the land. The rapidity of this movement is a strong influence in determining the character of the soil that is formed. With ready movement, waterlogging does not occur and there is little tendency towards the development of a heavy subsoil; while in a region underlain by impervious material at a comparatively shallow depth, or situated on an extensive level plane, water movement is slow and the tendency towards the development of a heavy, impervious subsoil is strong. As already stated, Fulton county was a level-lying drift plane prior to the cutting back of the streams. Under these circumstances the soils that developed on the Illinoian drift were developed under conditions favoring the accumulation or formation of an impervious soil. Had it not been for the fact that the loess deposit in Fulton county is sufficiently thick to eliminate largely any effect from the underlying drift, and the further fact that the cutting back of Spoon river prior to the deposition of the loess had established fairly good drainage for the region as a whole, the soils which we now have, formed from the loess, would have had much heavier subsoils. It is thus apparent that conditions in Fulton county subsequent to the deposition of the loess

have been favorable for the development of good soils. The proportion of dark-colored prairie soils is small because the well-established drainage lines have brought about conditions favorable to the growth of timber rather than grass.

SOIL CLASSIFICATION AND MAPPING

The soil type is the unit of classification in the Illinois soil survey. Each type thruout the area of its occurrence has the same soil characteristics and the same potential productivity tho it may differ, even on a single farm, in present producing power because of differences in the way the land has been managed. A soil type may be thought of as a kind of soil; and each kind or type is given a name, and for convenience, a number also. The type descriptions which follow are intended to give the reader a fairly clear idea of the characteristics of each type and to be of assistance in planning efficient management practices.

The failure to appreciate the fact that soil types are differentiated on the basis of the character of the entire profile, and not of the surface soil alone, often makes it difficult to understand what is meant by "soil type." It often happens that the surface soil of one type is no different from that of another type, and yet the two types may be widely different in character and in agricultural value. It is of the utmost importance in studying soil type descriptions to get a clear mental picture of the outstanding features of each type. This cannot be accomplished without some real study as there is no easy road to soil knowledge.

The accompanying soil map, shown in three sections, gives the location and boundary of each soil type and indicates the position of streams, roads, railroads, and towns. Table 1 gives the list of soil types, the area of each in square miles and in acres, and also the percentage each constitutes of the total area of the county.

TABLE 1.—SOIL TYPES OF FULTON COUNTY, ILLINOIS

Soil type No.	Name of type	Area in square miles	Area in acres	Percent of total area
5	Eroded Silt Loam	260.72	166 861	30.01
16	Brownish Yellow-Gray Silt Loam On Tight Clay	3.15	2 016	.36
18	Brownish Yellow-Gray Silt Loam	237.17	151 789	27.30
36	Light Brown Silt Loam	.08	51	.01
41	Brown Silt Loam	107.29	68 666	12.35
43	Brown Silt Loam On Clay	88.56	56 678	10.20
65	Black Clay Loam	1.32	845	.15
66	Black Clay Loam On Drab Clay	.28	179	.03
71	Drab Clay	7.56	4 838	.87
73	Brown Mixed Loam	113.01	72 326	13.01
81	Brown Silt Loam Over Sand Or Gravel	8.62	5 517	.99
133	Brown Sandy Loam Over Sand Or Gravel	2.45	1 568	.28
134	Brownish Yellow-Gray Silt Loam Over Sand Or Gravel	8.35	5 344	.96
136	Brown-Gray Silt Loam On Tight Clay Over Sand Or Gravel	.37	237	.04
	Water	1.90	1 216	.22
	Swamp	26.53	16 979	3.06
	Strip mines	1.40	896	.16
	Total	868.76	556 006	100.00

DESCRIPTION OF SOIL TYPES

Based on the principles explained above, the soils of Fulton county have been differentiated into fourteen soil types.

The dark-colored upland soils, indicated on the soil map by the numbers 36, 41, 43, 65, and 66, are the best soils in the county. They occupy 22.7 percent of the total area of the county. These soils differ among themselves in character, but they were all developed under a prairie-grass vegetation, as contrasted with a timber vegetation under which the light-colored soils developed. The dark-colored soils owe their dark color to the high organic-matter content imparted to them by the prairie-grass vegetation which grew on them prior to the occupation of these lands by the white man. In the lower lying areas the fibrous roots of the grasses were preserved from rapid decay by the swampy conditions that existed, and on the higher land they were preserved to a less extent by the mat of grass stems and leaves that accumulated. This mat was at times partially destroyed by prairie fires and was constantly decaying, but it was also being constantly renewed, and thru its protecting action it furthered the accumulation of organic matter in the soil. A forest cover is not favorable for the accumulation of soil organic matter, for the leaves and other debris on falling to the ground are exposed both to rapid decay and to complete destruction by forest fires.

As soon as virgin prairie land is plowed and put under cultivation or virgin timber is cleared and cultivated, the rate at which the organic matter decays is greatly accelerated. The amount of organic matter in the prairie soil when it was first plowed was probably greater than it would be necessary to maintain for agricultural purposes, but in the timber soils the original amount of organic matter was so limited that depletion by cultivation has been harmful. Special attention must now be given to increasing the amount of this valuable soil constituent in these light-colored soils if the best results are to be expected. On many farms the organic-matter content of the dark-colored soils also has been allowed to decrease to the danger point.

A brief description of the outstanding characters, together with a few suggestions for the practical management of each type, are given in the following paragraphs.

Eroded Silt Loam (5)

Eroded Silt Loam is an extensive soil type in Fulton county, covering 260.72 square miles, or 30 percent of the area of the county. It occupies the eroded areas between the streams and the level uplands and is in large part unsuited to general farming because of the steepness of the slopes. It has no well-developed and constant soil characteristics because of varying rates of erosion on different slopes, and cannot be considered a true soil type. Some slopes contain rock outcrop and others are gravelly towards the bottom.

Management.—This soil is, in the main, adapted only to pasture, orchard, or timber, tho there are slopes which, if carefully handled, may be farmed. Specific recommendations that will apply generally can scarcely be made.

Brownish Yellow-Gray Silt Loam On Tight Clay (16)

Brownish Yellow-Gray Silt Loam On Tight Clay occurs in Fulton county only in small areas on the remnants of the tabular divides. It is shown on the map as No. 16. It is a light-colored soil with a subsoil so impervious that it is doubtful whether it will tile-drain satisfactorily. Fortunately the total area of this type is not large, occupying a total of only 3.15 square miles.

The surface soil is a gray silt loam and contains many black iron pellets as does the surface soil of the "post-oak flats" in southern Illinois. These two soils are closely related in general character and in formation, but this soil as it occurs in Fulton county is much better than the post-oak land in southern Illinois. At about 7 or 8 inches in depth the subsurface layer is encountered. This layer differs from the surface layer in being lighter gray in color and in containing a greater abundance of black iron pellets. At about 16 inches in depth the heavy subsoil is encountered. This layer breaks up into large, angular blocks. These blocks are heavily coated with light gray material which is similar to the subsurface layer; the interior of the blocks is light brown or yellowish brown with pale yellow spots. This subsoil layer continues to a depth of about 30 inches with little change except that the coating is drabbish brown at 18 or 20 inches in depth and drab near the bottom of the layer. The subsoil is compact and plastic thruout and does not permit ready water movement. Below about 30 inches the material becomes more friable and the color becomes predominately reddish brown.

Management.—Brownish Yellow-Gray Silt Loam On Tight Clay is the poorest upland soil in Fulton county. Its flat, nearly level topography and relatively impervious subsoil make drainage difficult, altho the small size of the areas of this type makes it relatively easy to remove surface water by means of furrows and open ditches. This soil is strongly acid and very low in nitrogen and organic matter. The ability of sweet clover to grow on soils of this character, following the correction of the acid condition with limestone, suggests that this crop be grown and used for pasture. Following the sweet clover it should be possible to grow satisfactory corn except during seasons which are climatically unfavorable. No treatment other than limestone, manure, and the growing of sweet clover is advised for this soil.

Brownish Yellow-Gray Silt Loam (18)

Brownish Yellow-Gray Silt Loam occurs on gently undulating portions of the tabular divides that remain as narrow irregular areas between the eroded land on either side. It may be thought of as occupying the outer timber-soil belt, with the exception of the flat, nearly level portions, which are occupied by type No. 16 described above. This type occurs only in relatively small and very irregular areas but occupies a total of 237.17 square miles in Fulton county.

The surface soil is brownish gray in color and extends to a depth of about 8 inches. It is silt loam in texture with an appreciable amount of very fine sand near the Illinois bluffs. The subsurface differs from the surface layer in having a distinctly yellowish cast, the degree of yellowness increasing as the

degree of slope increases. The subsoil, which is compact and somewhat plastic, is encountered at a depth of 12 to 16 inches. It breaks into large angular pieces and these pieces are coated with gray, silty material in the upper portion of the layer and with dark brown or reddish brown material in the lower portion. At a depth varying from 25 to 36 inches a friable mixed gray and reddish brown material occurs.

Management.—This soil is medium-acid and is low in organic matter. It will grow fairly good red clover during exceptionally favorable clover years, but the proportion of failures is too great to justify attempting this crop without first testing the soil and applying the necessary amount of limestone. Directions for making these tests may be found in Circular 346 of this station. Sweet clover or alfalfa will not grow on this soil without limestone. Drainage is usually good. The subsoil is permeable to water and the slope is usually sufficient for good surface drainage. A good short rotation for improving the producing capacity of this soil is corn and oats with sweet clover in the oats to be plowed down in the spring for corn. No fertilizer treatment is advised for this soil until after the nitrogen and organic-matter deficiencies have been corrected by the use of a good cropping system properly handled.

Light Brown Silt Loam (36)

Light Brown Silt Loam is a very minor type in Fulton county, occupying a total of only about one-twelfth of a square mile. This soil is somewhat acid and is low in organic matter for a prairie soil. It has no well-developed profile, but it is distinctly reddish brown is the upper 30 or 40 inches with the exception of the thin surface layer, which is light brown.

Management.—The management of this soil should take into account the need for organic matter and nitrogen and the tendency to erode.

Brown Silt Loam (41)

Brown Silt Loam is the most extensive dark-colored soil in Fulton county. It occupies a total of 107.29 square miles and occurs on undulating to rolling topography.

The surface soil of this type is brown when dry and very dark brown or black when moist. It is a silt loam in texture and varies from 7 to 9 or 10 inches in depth. The subsurface is lighter in color than the surface and extends to a depth of about 18 inches. The subsoil is yellowish brown with a light brown coating on the surfaces of the somewhat angular fragments into which this material easily breaks. This layer extends to a depth of about 32 inches and is medium-compact and only slightly plastic. The material below the subsoil layer is very friable and permeable.

Management.—Brown Silt Loam has good surface drainage and good underdrainage. Erosion is a minor problem on this type and may be easily controlled by reasonably good farming methods including the use of a good cropping system. A medium application of limestone is needed for the growth of alfalfa or sweet clover and for the best growth of red clover. This type is well adapted

to alfalfa. The organic-matter supply has been allowed to become somewhat depleted on many farms and attention should be given to providing for the return, at regular and frequent intervals, of fresh organic materials, including legume residues and manure. The results from the Kewanee experiment field, given on pages 22 to 25, may be taken as a guide for the treatment of this soil.

Brown Silt Loam On Clay (43)

Brown Silt Loam On Clay may be rather readily distinguished from Brown Silt Loam by its different topographic position. It occurs only on the more level-lying areas which have not yet been dissected by the small drainage lines that are constantly cutting back into the tabular divides. This type occupies 88.56 square miles and is important both because of its extent and its productiveness.

The surface soil extends to a depth of about 8 inches and is a dark brown to black silt loam. The subsurface layers are a little heavier than the surface soil and are black in color. The subsoil lies at a depth of about 18 to 20 inches; it is medium-plastic and breaks into angular fragments the surfaces of which are coated with black. At about 35 inches the material becomes friable and is mixed reddish brown and drab in color. Root channels were found to be numerous to the depth examined, 48 inches.

Management.—Brown Silt Loam On Clay is a productive soil. Its topography is such that natural surface drainage is not very good but it underdrains well and good outlets are usually available. The organic-matter content of this soil is high, but this fact should not be taken to mean that regular additions of organic materials are not necessary. If sweet clover is to be grown, a light to medium application of limestone is necessary. The soil should be tested as outlined in Circular 346 of this station before applying limestone, for there is considerable variation in degree of acidity and, by testing, the limestone can be applied where and in the amounts needed, thus effecting a considerable saving. If sweet clover is grown and plowed down for corn, it is questionable whether the use of other fertilizing materials will result in sufficient increases in crop yields to pay a profit.

The results of experiments on the Aledo field, an account of which is given on pages 25 to 27, will be of interest in this connection.

Black Clay Loam (65) and Black Clay Loam On Drab Clay (66)

These two soil types are of minor importance because of their limited extent, the former occupying a total of only 1.32 square miles and the latter little more than a quarter of a square mile. They are both potentially productive soils and yield good crops consistently if well underdrained. They occupy the low-lying places in the prairie regions of the county and differ in that No. 66 has much the heavier and grayer subsoil.

The surface soil of both types is heavy and black and granulates well unless plowed when too wet. The subsurface layer of Type 65 differs from the corresponding layer in Type 66 in being somewhat less heavy and in having a slightly yellowish cast instead of being drab or grayish drab in color.

Management.—Neither of these soils is acid and both are well supplied with organic matter tho it is essential to plow down fresh supplies of organic material at intervals if a poor physical condition of the soil is to be avoided. The use of fertilizing materials on these soils is not advised at present, as their use would almost certainly prove to be unprofitable.

Drab Clay (71)

Drab Clay is a bottom-land soil occurring in the Illinois river bottom. It is mapped as occupying a total area of 7.56 square miles. It is formed from sediment deposited in quiet water and is therefore fine textured. Frequent overflow during recent years has resulted in rather rapid change in the character of the soils occupying the area shown on the map as No. 71.

The surface soil is, for the most part, drabbish brown in color and heavy. There is little or no subsurface or subsoil development. This land grows good corn and needs only complete protection from overflow and good drainage to be good general farming land.

Brown Mixed Loam (73)

Brown Mixed Loam occupies the small bottoms, the Spoon river bottom, and the Illinois river bottom, where sediment from the adjacent uplands has been deposited. It is a youthful soil and subject to frequent change because of overflow. It is a productive soil, but in many places the problems of flood protection and drainage have not been satisfactorily solved.

Brown Silt Loam Over Sand Or Gravel (81)

Brown Silt Loam Over Sand Or Gravel is a terrace type; that is to say, a soil formed over sand or gravel which was deposited from an ancient stream. It occurs in small areas along the Spoon and Illinois river bottoms. There is considerable variation in this soil with respect to character of the surface, subsurface, and subsoil and in depth to the sand and gravel strata. In places recent wash from the adjacent bluffs constitutes a greater or less proportion of the entire profile, while in others no recent wash is present and the soil is very similar to corresponding dark-colored upland soils. Underdrainage is usually better than on the upland because of the underlying sand and gravel strata.

Management.—Little can be said about the management of this terrace soil because of the variations that occur in it. The need for limestone should be determined by testing, as directed in Circular 346, and provision should be made for the return of leguminous organic matter as this soil is generally somewhat deficient in this important constituent.

Brown Sandy Loam Over Sand Or Gravel (133)

Brown Sandy Loam Over Sand Or Gravel is of little importance, occupying a total of less than 2.5 square miles. The sandy material composing it is of wind and water origin. Most of the areas show little profile development. Areas which are farmed should receive frequent additions of organic matter, as both organic matter and nitrogen are readily lost from this soil. Therefore small frequent

additions of manure or other organic matter are better than infrequent large additions. Limestone is required for sweet clover or alfalfa, but it should not be applied without first testing the soil as directed in Circular 346.

Brownish Yellow-Gray Silt Loam Over Sand Or Gravel (134)

Brownish Yellow-Gray Silt Loam Over Sand Or Gravel occupies a total of 8.35 square miles. Much of it is farmed and it does not differ materially, except in origin, from Type 18 described on page 11.

Brown-Gray Silt Loam On Tight Clay Over Sand Or Gravel (136)

Brown-Gray Silt Loam On Tight Clay Over Sand Or Gravel occupies a total of only 237 acres and is of very little importance because of its small extent and low value. It is a terrace formation and has an impervious subsoil. Further information about this soil may be had by anyone interested, thru correspondence with the Agricultural Experiment Station.

CHEMICAL COMPOSITION OF FULTON COUNTY SOILS

In the Illinois soil survey each soil type is sampled in the manner described below and subjected to chemical analysis in order to obtain a knowledge of its important plant-food elements. Samples are taken, usually in sets of three, to represent different strata in the top 40 inches of soil, namely:

1. An upper stratum extending from the surface to a depth of 6⅔ inches. This stratum, over the surface of an acre of the common kinds of soil, includes approximately 2 million pounds of dry soil.
2. A middle stratum extending from 6⅔ to 20 inches and including approximately 4 million pounds of dry soil to the acre.
3. A lower stratum extending from 20 to 40 inches and including approximately 6 million pounds of dry soil to the acre.

By this system of sampling three zones for plant feeding are represented separately. It is with the upper, or surface layer, that the following discussion is mostly concerned, for it includes the soil that is ordinarily turned with the plow and is the part with which the farm manure, limestone, phosphate, or other fertilizing material is incorporated. Furthermore it is the only stratum that can be greatly changed in composition as a result of adding fertilizing materials.

For convenience in making application of the chemical analyses, the results presented in Tables 2, 3, and 4 are given in terms of pounds per acre. It is a simple matter to convert these figures to a percentage basis in case one desires to consider the information in that form. In comparing the different strata, it must be kept in mind that the composition of each is based on different quantities of soil, as indicated above. The figures for the middle and lower strata must therefore be divided by two and three respectively before being compared with each other or with the figures for the upper stratum.

Great Variation in Chemical Composition

The most striking variations in the chemical makeup of the soils of Fulton county are to be found in the lighter colored timber soils skirting the Illinois

TABLE 2.—FULTON COUNTY SOILS[1]: PLANT-FOOD ELEMENTS IN UPPER SAMPLING STRATUM, ABOUT 0 TO 6⅔ INCHES

Average pounds per acre in 2 million pounds of soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
16	Brownish Yellow-Gray Silt Loam On Tight Clay...	21 730	2 030	890	380	34 990	6 700	7 690
18	Brownish Yellow-Gray Silt Loam..	22 680	2 220	850	760	34 560	6 120	7 690
41	Brown Silt Loam...	57 450	4 730	1 130	900	33 140	9 540	11 608
43	Brown Silt Loam On Clay........	63 940	4 920	1 180	720	32 450	9 730	12 230
65	Black Clay Loam...	80 360	6 340	1 590	920	30 330	12 800	19 490

[1]The samples representing the respective types were taken in neighboring counties. The less extensive types and some that are highly variable in their characteristics are not included in these analyses.

river and smaller streams, in contrast with the darker colored prairie soils occupying the intervening areas. The chemical analyses of the major types of upland soils in the county are summarized in Tables 2, 3, and 4.

While all the chemical elements studied, with the exception of potassium, vary within wide limits, it may be observed that the nonmetallic elements—carbon, nitrogen, phosphorus, and sulfur—all vary more or less in a parallel relationship. The reason for this is that all these elements are associated to a greater or less extent with the organic matter of the soil.

Nitrogen Closely Associated With Organic Matter

Being approximately half carbon, the organic matter of the soil is measured by the organic carbon. Soil nitrogen is practically all combined in the organic form, constituting about one-twentieth of the organic matter. In fresh organic materials the proportion of nitrogen is much less than in older materials, in which decay has taken place, for in the process of decay the carbon is oxidized

TABLE 3.—FULTON COUNTY SOILS[1]: PLANT-FOOD ELEMENTS IN MIDDLE SAMPLING STRATUM, ABOUT 6⅔ TO 20 INCHES

Average pounds per acre in 4 million pounds of soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Tocal potassium	Total magnesium	Total calcium
16	Brownish Yellow-Gray Silt Loam On Tight Clay....	15 090	1 910	1 550	400	73 430	19 630	14 190
18	Brownish Yellow-Gray Silt Loam..	14 010	2 030	1 550	740	69 420	21 230	15 650
41	Brown Silt Loam...	73 580	6 350	1 890	1 280	66 900	22 640	21 370
43	Brown Silt Loam On Clay........	85 680	6 890	1 940	1 230	65 730	22 910	23 500
65	Black Clay Loam...	92 740	7 350	2 650	1 240	62 840	26 560	35 700

[1]The samples representing the respective types were taken in neighboring counties. The less extensive types and some that are highly variable in their characteristics are not included in these analyses.

TABLE 4.—FULTON COUNTY SOILS[1]: PLANT-FOOD ELEMENTS IN LOWER SAMPLING STRATUM, ABOUT 20 TO 40 INCHES
Average pounds per acre in 6 million pounds of soil

Soil type No.	Soil type	Total organic carbon	Total nitrogen	Total phosphorus	Total sulfur	Total potassium	Total magnesium	Total calcium
16	Brownish Yellow-Gray Silt Loam On Tight Clay....	18 180	2 580	3 160	540	104 460	46 960	29 300
18	Brownish Yellow-Gray Silt Loam..	15 280	2 370	3 010	840	100 620	46 780	26 390
41	Brown Silt Loam...	34 900	3 780	2 440	1 080	100 340	48 000	33 870
43	Brown Silt Loam On Clay.........	37 420	3 510	2 500	980	98 240	48 070	36 650
65	Black Clay Loam...	39 830	3 370	3 420	540	98 880	45 980	48 650

[1]The samples representing the respective types were taken in neighboring counties. The less extensive types and some that are highly variable in their characteristics are not included in these analyses.

and lost much more rapidly than is the nitrogen and so the ratio of nitrogen to carbon gradually narrows. The nitrogen-carbon ratio tends also to become much more narrow with increasing depth of soil, particularly in the more mature soil types. This is to be expected in view of the fact that the organic matter in the deeper levels is older, and is replenished with fresh plant residues to a less extent than is that nearer the surface. In the soils of Fulton county the nitrogen-carbon ratio drops from an average of 1:11.7 in the surface soil to 1:9.0 in the lower stratum. If only the more mature types be considered the narrowing of this ratio will be seen to be even more pronounced.

In addition to the change in the chemical character of the organic matter with increasing depth, as shown by the nitrogen-carbon ratios, there is a very definite decrease in the *total amount* of organic matter present with increasing depth. This falling off in amount of organic matter is observable to some extent in the middle sampling stratum but is much more pronounced in the lower stratum.

Light-Colored Soils Low in Phosphorus

In contrast to nitrogen, only one-fourth to one-third of the phosphorus in most soils exists in various organic forms. Hence variations in the amounts of phosphorus in the different soils are more nearly independent of the organic matter than is the case with nitrogen, especially in the lower levels, where the organic matter is not abundant and most of the phosphorus exists in mineral combinations. The soils poorest in total phosphorus content, so far as the upper strata are concerned, are the light-colored timber soils, Types 16 and 18, which are also lowest in their organic-matter content. These types are well supplied with phosphorus, however, in the lower stratum.

The Sulfur Cycle

Less is known of the state in which sulfur is combined in soils. The amounts present, however, tend in general to be much lower than those of phosphorus.

While crops take as much sulfur as phosphorus from the soil, or even more, sulfur deficiencies do not ordinarily develop because of the supply of this element in the atmosphere. The sulfur dioxid which escapes into the air in the burning of wood and coal is brought to the earth dissolved in rain water, the amount added ranging in different parts of the state from one to three or more pounds of sulfur an acre a month. This is more than enough to supply the requirements of maximum crops.

Potassium Content Comparatively Uniform

The potassium content of Fulton county soils shows relatively less variation from type to type than any other element studied. The average amount in the surface soil is approximately 33,100 pounds an acre, and the variation among all the types reported is very small. The potassium concentration in the soil at different depths likewise shows very little variation, averaging about 33,800 pounds an acre in the middle stratum, and 33,500 pounds in the lower, after correcting for the varying thickness of the different strata.

Wide Variations in Calcium and Magnesium

The wide variations in the calcium and magnesium contents of the soils of Fulton county are related to the intensity of leaching and other weathering processes involved in soil development.

Aside from the calcium that may be in solution in the soil water, calcium exists primarily in three forms. *Calcium-aluminum silicates* are complex soil minerals which decompose but slowly and furnish but scant amounts of soluble calcium for plant growth. This is the form which predominates in most soils, particularly in those which are highly acid. Calcium may be deficient for plant growth in such soils, so that the supplying of this element in readily available form may be one of the benefits of liming. Calcium also occurs in association with the soil colloids (the finest of the clay particles) by which it is absorbed; this is known as *replaceable calcium*, and is much more easily obtained by growing plants than the mineral form above mentioned. It is found more abundantly in the soils which are nonacid or only slightly acid. Types are occasionally found that grow sweet clover luxuriantly because of the high degree of saturation of their colloids with replaceable calcium, even tho they may actually be somewhat acid. *Calcium carbonate*, the form contained in limestone, is the third form of calcium in soils. It occurs only in alkaline (sweet) soils. Of the three forms of calcium this is the one most readily dissolved in the soil water and leached to lower and lower levels as weathering proceeds, much of it eventually being removed entirely in the drainage water. This weathering and leaching process has continued to such an extent in Fulton county that probably all the surface soils in the county are free from carbonates and the majority of the types are found to contain no calcium or magnesium in this form within the upper 40 inches. These statements concerning soil calcium apply in general also to the magnesium compounds in the soil.

Even after the carbonates have disappeared there continues a gradual release of the replaceable calcium and magnesium, which are taken up in part by

growing plants and thus removed mainly from the surface soil in harvested crops, but which are also continually being carried down by the soil water. This removal goes on at very different rates for calcium and magnesium. Either because of the more rapid loss of replaceable calcium or because of the greater reabsorption of part of the magnesium by soil colloids, the *proportionate* amount of magnesium as compared with calcium increases with increasing depth.

This changing of the ratio of magnesium to calcium in the lower levels is a function of the aging or approaching maturity of the soil. It is very pronounced in mature types but has proceeded to only a slight extent or not at all in young or immature soils. For example, it may be computed from the calcium and magnesium data in Tables 2, 3, and 4 that in Type 16, one of the mature types, the magnesium-calcium ratios are, for the upper, middle, and lower strata respectively, .87, 1.38, and 1.60. That is, in the surface soil there is present .87, or about nine-tenths, as much magnesium as calcium; in the middle stratum the magnesium is slightly in excess; while in the lower one the magnesium is more than one and one-half times as great as the calcium. In a typically immature or youthful soil such as Black Clay Loam, Type 65, these ratios are low and more nearly equal, being for the three strata .67, .76, and .95 respectively. While these figures all refer to the *total* calcium and magnesium, it has been definitely shown by other investigations at this Station that it is the more mobile, or *replaceable*, portion of these elements which is chiefly concerned in the shifting that results from leaching.

From these observations, it is obvious that some of the processes involved in soil development are definitely reflected in the chemical properties of the soil itself. These, in turn, may be related to agricultural utilization and to fertility requirements.

Local Tests for Soil Acidity Often Required

The accompanying tables, it will be noted, contain no figures purporting to represent either the lime requirement or the limestone present in the different soil types. This is because it is impracticable to attempt to obtain an average quantitative measure either of the calcium-carbonate content of a given soil type or of its acidity. While some samples will contain large amounts of calcium carbonate (a condition probably not encountered in Fulton county) others will contain none but, on the other hand, may have a lime requirement due to soil acidity. We thus have what may be considered positive and negative values ranging, perhaps widely, on the opposite sides of the zero or neutral point. The numerical average of such values could have no significance whatever, since such an average would not necessarily even approach the condition actually existing in a given farm or field.

The qualitative field tests made during the process of the soil survey are much more numerous than the chemical analyses made in the laboratory, and they give a general idea of the predominating condition in the various types as to acidity or alkalinity. These tests, therefore, furnish the basis for some general recommendations which are given in the descriptions of individual types on pages 10 to 15. To have a sound basis for the application of limestone, the

owner or operator of a farm will, however, usually find it desirable to determine individually the lime requirements of his different fields. The section in the Appendix dealing with the application of limestone (page 34) is pertinent and should be read in this connection.

Character of Chemical Combination Related to Availability

It has been seen that a given plant-food element exists in the soil in various forms, or chemical combinations. Thus soil phosphorus is found partly in organic form and partly in inorganic, or mineral, combinations. These forms differ from each other, not only in the rates at which they become available to growing crops, but also in the way in which their availability to crops is affected by soil conditions. Calcium has been observed to be present sometimes as *calcium carbonate,* a form that is quickly available to crops; sometimes as *replaceable calcium,* a form somewhat less active than calcium carbonate; and also as *calcium-alumino-silicates*, minerals that decompose very slowly. Statements of similar import might be made concerning nitrogen, sulfur, and other elements. Moreover, the proportions in which the different forms of an element occur vary in different soils.

Thus, the rate at which plant-food elements become available is extremely important; a knowledge of merely the total amounts of these various elements present in a soil does not furnish sufficient information for complete guidance for the application of fertilizers.

Service of Chemical Investigations in Soil Improvement

While the chemical investigations carried out in connection with the soil survey (of which the analyses here reported are a part) may not all serve directly as a complete guide in the use of fertilizers, they are nevertheless of special value in two ways.

In the first place such investigations reveal at once any *outstanding* deficiencies in the amounts of the various plant-food elements present—deficiencies so large that soil productivity would be affected regardless of other conditions. For instance, peat soils usually lack sufficient potassium to grow crops. This condition is revealed at once by the chemical analysis and the proper corrective measure is obvious. Small differences in the amount of a plant-food element, however, do not necessarily indicate corresponding differences in fertilizer need. Differences in phosphorus content as small as 100 or 200 pounds an acre, for example, should not be considered as indicating corresponding differences in the need for phosphate fertilization. In the case of nitrogen ordinary chemical analysis does not distinguish between active and inactive forms. One hundred pounds of active nitrogen added by plowing down a clover crop may be of more importance to the succeeding crop than 1,000 pounds of soil nitrogen if only a small part of it happens to be in a form that plants can use.

As examples of the direct use of chemical analysis in soil improvement may be cited the tests for soil acidity, for carbonate, and for available phosphorus.

The second use of chemical methods is in the more detailed study of soils. The processes of soil development leave their imprint upon the soil both in its

physical conformation and in its chemical characteristics. Likewise every operation in the handling of the soil and every application of fertilizer or liming material disturbs its equilibrium, setting up new reactions, which are in turn reflected in variations in crop adaptability, producing capacity, and agricultural usefulness. Chemistry is a most important tool in tracing and characterizing such changes. Chemical investigations are undertaken, therefore, with the aim of aiding in the classification of soils as well as making possible more accurate prediction of their agricultural value and fertility needs and their response to different methods of management.

FIELD EXPERIMENTS ON SOIL TYPES SIMILAR TO THOSE IN FULTON COUNTY

The University of Illinois has conducted altogether about fifty soil experiment fields in different sections of the state and on various soil types. Altho some of these fields have been discontinued, the majority are still in operation. It is the present purpose to report the summarized results from certain of these fields located on soil types described above. For a more complete report of the work on these fields the reader is referred to Bulletin 362, "Response of Illinois Soils to Systems of Soil Treatments," and Bulletin 370, "Crop Yields from Illinois Soil Experiment Fields in 1930."

A few general explanations at this point, which apply to all the fields, will relieve the necessity of numerous repetitions in the following pages.

Size and Arrangement of Fields. The soil experiment fields vary in size from less than two acres up to forty acres or more. They are laid off in series of plots, the plots commonly being either one-fifth or one-tenth acre in area. Each series is occupied by one kind of crop. Usually there are several series so that a crop rotation can be carried on with each crop represented every year.

Farming Systems. On most of the fields the treatment provides for two distinct systems of farming, livestock farming and grain farming.

In the livestock system, stable manure is used to furnish organic matter and nitrogen. The amount applied to a given plot is based upon the amount that can be produced from crops raised on that plot.

In the grain system no animal manure is used. The organic matter and nitrogen are applied in the form of plant manures, including the plant residues produced, such as cornstalks, straw from wheat, oats, clover, etc., along with leguminous catch crops plowed under. It was the plan in this latter system to remove from the land, in the main, only the grain and seed produced, except in the case of alfalfa, that crop being harvested for hay the same as in the livestock system, but certain modifications have been introduced in recent years, as explained in the descriptions of the respective fields.

Crop Rotations. Crops which are of interest in the respective localities are grown in definite rotations. The most common rotation used is wheat, corn, oats, and clover; and often these crops are accompanied by alfalfa growing on a

fifth series. In the grain system a legume catch crop, usually sweet clover, is included, which is seeded on the young wheat in the spring and plowed under in the following spring in preparation for corn. If the red clover crop fails, soybeans are substituted.

Soil Treatment. The treatment applied to the plots at the beginning was usually standardized according to a rather definite system. With advancing experience, however, new problems arose calling for new experiments, so that on many of the fields plots have been divided and a portion given over to new systems of treatment, at the same time maintaining the original system essentially unchanged from the beginning.

Following is a brief explanation of this standard system of treatment.

Animal Manures.—Animal manures, consisting of excreta from animals, with stable litter, are spread upon the respective plots in amounts proportionate to previous crop yields, the applications being made in the preparation for corn.

Plant Manures.—Crop residues produced on the land, such as stalks, straw, and chaff, are returned to the soil, and in addition a green-manure crop of sweet clover is seeded in small grains to be plowed under in preparation for corn. (On plots where limestone is lacking the sweet clover seldom survives.) This practice is designated as the *residues system.*

Mineral Manures.—Limestone has usually been applied at the rate of 4 tons an acre as an initial application, and 2 tons an acre every four years thereafter until a considerable excess has accumulated in the soil. Rock phosphate has been applied at the rate of one ton an acre at the beginning, followed by an annual acre-rate of 500 pounds applied once in the rotation until a considerable excess has accumulated. Potassium has been applied usually in the form of 200 pounds of kainit a year. When kainit was not available, owing to conditions brought on by the World War, potassium carbonate was used.

Explanation of Symbols Used. In the presentation of the data much use is made of the following symbols:

0 = Untreated land or check plots
M = Manure (animal)
R = Residues (from crops, and includes legumes used as green manure)
L = Limestone
P = Phosphorus, in the form of rock phosphate unless otherwise designated, (sP = superphosphate, bP = bone meal, rP = rock phosphate, slP = slag phosphate)
K = Potassium (usually in the form of kainit)
( ) = Parentheses enclosing figures, signifying tons of hay, as distinguished from bushels of seed

KEWANEE FIELD

The Kewanee experiment field, located in Henry county, represents the soil type Brown Silt Loam, which occupies about 12 percent of the area of Fulton county.

This field has been in operation since 1915. It includes 20 acres of the dark-colored loessial soil characteristic of the region. Altho the main soil type represented is Brown Silt Loam, a detailed examination reveals the presence of a second type, Black Clay Loam on Drab Clay, occupying the basin of the

draw which traverses the field in a winding direction. In topography the land is rather rolling and has a tendency to wash at certain spots. The field is laid out in two systems of plots designated as the major and the minor series. The major system is devoted to the regular series of tests and the minor to a special phosphate study.

The Major Series

A rotation system of wheat, corn, oats, and clover has been practiced on the major series, the crops being managed mainly as described on pages 21 and 22. Since 1921 the clover on the residues plots has been harvested for hay instead of seed and the oat straw has not been returned to the land. The periodic application of limestone has been suspended since 1922, the different series at that time having received an average total of 6¾ tons an acre; no more is to be applied until it is needed. The practice of returning the wheat straw was discontinued with the 1922 crop; and since 1925 only one crop a year of clover hay on the residues plots has been removed, the second crop being plowed down as green manure. The rock phosphate applications were suspended in 1927 after evening up all phosphate plots to a total of 4 tons of rock phosphate an acre.

A summary of the crop yields obtained since the complete soil treatments have been in effect is given in Table 5. Table 6 gives some of the financial results based upon records of the last crop rotation period.

In productiveness the Kewanee field ranks among the highest of the Illinois experiment fields. During the past fourteen years the untreated land has produced an average of 29 bushels of wheat and 54 bushels of corn an acre, and the annual acre-value of the crops produced in the last rotation period has been $27.55.

This land is highly responsive to stable manure, all crops participating in the benefit from its application. The acre-value of crop increase produced from manure alone has amounted to $8.25 a year for the past four years. On the other hand, residues used alone have had little or no effect; in fact, the records show a negative value for residues where not accompanied by limestone.

TABLE 5.—KEWANEE FIELD: GENERAL SUMMARY OF CROP YIELDS
Average Annual Crop Yields 1917-1930—Bushels or (tons) per acre

Serial plot No.	Soil treatment	Wheat *12 crops*	Corn *14 crops*	Oats *14 crops*	Clover[1] *13 crops*
1	0	29.0	54.1	58.5	(1.70)
2	M	32.5	66.3	71.4	(2.30)
3	ML	35.5	70.8	73.1	(2.42)
4	MLP	40.1	72.3	72.2	(2.59)
5	0	29.7	55.6	60.7	(1.71)
6	R	32.2	59.3	59.0	(1.40)
7	RL	34.6	68.1	63.0	(1.65)
8	RLP	40.2	71.8	69.5	(1.85)
9	RLPK	41.6	75.1	70.9	(1.90)
10	0	29.4	51.1	54.9	(1.43)

[1]Some clover seed evaluated as hay.

TABLE 6.—KEWANEE FIELD: SOME FINANCIAL RESULTS BASED ON CROP YIELDS FOR THE ROTATION PERIOD ENDED IN 1930
Figures indicate average annual acre-values

Untreated land, acre-value of *all crops*	$27.55
Acre-value of *crop-increase* from—	
Manure, alone	$ 8.25
Residues, alone	−1.94
Limestone, used with manure	3.50
Limestone, used with residues	3.72
Rock phosphate, used with manure and limestone	2.66
Rock phosphate, used with residues and limestone	3.86
Potash, used with residues, lime, and rock phosphate	1.82
Net acre-value of *crop-increase* under most profitable treatment—	
In livestock system (manure, limestone)	$7.99
In grain system (residues, lime, rock phosphate)	2.03
Net acre-value of *total crops* under most profitable treatment—	
In livestock system (manure, limestone)	$35.76
In grain system (residues, lime, and rock phosphate)	29.80

Limestone has played an interesting role in soil improvement on this field. In the earlier years it was not so important, but with the passing of time and the changing of soil conditions limestone has become highly essential in the scheme of improvement whether in the manure or in the residues system of treatment. The crop increase ascribed to limestone has been worth during the last rotation $3.50 an acre a year where applied with manure and $3.72 where applied with residues.

Rock phosphate, like limestone, has produced increasing returns with the progress of the work. Where used with manure it is not yet on a paying basis, but in the residues system it has now become an essential part of the most profitable of the various treatments under comparison; namely, the residues, limestone, rock phosphate combination.

The response to potassium fertilization has not been sufficient to pay the cost.

Summarizing the results on the basis of the last crop rotation, it appears that in the livestock system manure with limestone is giving the most profitable returns, the value of the crop increases amounting to $7.99 an acre annually. In the grain system it is the combination residues, lime, and phosphate that is giving the highest net returns, the annual increases in crops being worth $2.03 an acre. As shown in the last two lines of Table 6, the net acre-value of the total crops produced under these treatments is $35.76 and $29.80 in the two systems respectively.

Comparative Phosphate Experiments.

Four short series having only 4 plots each constitute the so-called minor system on the Kewanee field. These plots are now given over to a comparison of the effectiveness of rock phosphate and superphosphate.

TABLE 7.—KEWANEE FIELD: PHOSPHATE EXPERIMENTS
Average annual crop yields 1922-1930—bushels or (tons) per acre

Serial plot No.	Soil treatment	Wheat	Corn	Oats	Clover	Value per acre[1]
		9 crops	*9 crops*	*9 crops*	*9 crops*	
1	RrP	43.1	72.3	72.0	(2.83)	$40.64
2	RsP	44.7	72.4	74.0	(2.71)	40.71
3	RLrP	39.7	75.5	73.4	(2.72)	39.85
4	RLsP	46.3	76.0	75.9	(2.73)	42.01

[1]Based on the following prices: wheat, $1.10; corn, 69 cents; oats, 37 cents; clover, $13.40.

Alfalfa was grown on these plots until 1922. In the beginning, limestone was applied to Plots 3 and 4 at the rate of 4 tons an acre. This application was repeated in 1919. In 1922 the present experiments with phosphates were begun and the same rotation practiced on the larger series described above was established on these series. In this comparison rock phosphate is used on Plots 1 and 3 at the annual rate of 400 pounds an acre, applied once in the rotation ahead of the wheat, but beginning with 1927 rock phosphate has been applied at the same time as the superphosphate. Superphosphate is used on Plots 2 and 4 at the annual rate of 200 pounds an acre. It is applied twice in the rotation, one-half for wheat and one-half for oats. A summary of the annual crop yields and corresponding money values is given in Table 7.

Without limestone practically no difference is found in value of crops produced under the two forms of phosphate. In the presence of limestone the difference in crop values is $2.16 an acre a year in favor of superphosphate. Wheat has been the crop most affected by the form of phosphate applied.

It is to be borne in mind that the order of values can easily be shifted by a change in the relative yields of the respective crops or by a change in commodity prices. Furthermore no consideration has been given here to any possible difference in the residual effects of the two forms of phosphate which might appear upon discontinuing the treatments.

ALEDO FIELD

An experiment field representing the soil type Brown Silt Loam On Clay is located in Mercer county just west of Aledo. This field has been in operation since 1910. From its physical aspects this field should be well adapted to experimental work, the land being unusually uniform in topography and in soil profile.

There are two general systems of plots and they are designated as the major and the minor systems. The major system comprizes four series made up of 10 plots each. The plots were handled substantially as described for standard treatment until 1918, when it was planned to harvest the first crop of red clover on the residues plots for hay and to plow down the second crop if no seed were formed. In 1921 the return of the oat straw was discontinued. In 1923 the rotation was changed to one of corn, corn, oats and wheat. In this rotation it was planned to seed hubam clover in the oats on all plots, for use as hay or for soil improvement, and common sweet clover in the wheat on the

TABLE 8.—ALEDO FIELD: GENERAL SUMMARY OF CROP YIELDS
Average annual crop yields 1912-1930—bushels or (tons) per acre

Serial plot No.	Soil treatment	Wheat *16 crops*	Corn *27 crops*	Oats *18 crops*	Clover[1] *6 crops*	Soybeans *3 crops*
1	0	29.7	54.8	59.7	(2.21)	(1.60)
2	M	34.9	68.7	67.2	(2.74)	(1.63)
3	ML	35.7	68.5	70.2	(3.12)	(1.60)
4	MLP	37.7	73.0	71.2	(3.05)	(1.61)
5	0	30.5	56.4	60.6	(2.00)	16.1
6	R	31.7	62.6	62.5	(1.91)	16.5
7	RL	34.3	70.1	67.8	(1.96)	18.8
8	RLP	37.4	72.4	69.2	(2.08)	20.3
9	RLPK	37.8	74.0	71.4	(1.73)	20.9
10	0	29.9	54.7	59.8	(2.38)	(1.62)

[1]Some clover seed evaluated as hay.

residues plots for use as a green manure. Since this change, no residues except cornstalks and the green manure have been returned to the residues plots. The limestone applications were temporarily abandoned in 1923 after the different series had received 7½ to 9 tons an acre and no more will be applied until a need for lime appears. The phosphate applications were evened up to a total of 4 tons an acre in 1924, and no more will be applied for some time at least.

A summary of the results, showing the average annual yields obtained for the period beginning when complete soil treatment came into sway is given in Table 8.

A study of the financial returns of the last crop rotation (ending 1930) was recently reported in Bulletin 370 of this Station. Certain results of this study are brought together in Table 9. For prices of crops and cost of treatments employed in this study the reader is referred to the above-mentioned bulletin.

Looking over the data of these two tables one may observe first the rather high natural productiveness of this soil. On the untreated check plot sixteen crops of wheat have produced an average yield of about 30 bushels an acre and twenty-seven crops of corn have averaged around 55 bushels an acre. The average annual acre-value of all crops produced in the last rotation period on land without treatment amounted to $30.29.

The value of animal manure on this land is well demonstrated in the increased yields on the manure plots, the corn crop being especially responsive. Used alone, stable manure has produced increases in crop yields during the last rotation worth about $8 an acre a year. This suggests the importance of carefully conserving and regularly applying all animal manure produced.

Crop residues have been beneficial to the corn but seem to have had little effect on the other crops. About $3 represents the annual acre-value of the crop increases ascribable to the simple residues treatment during the past four years.

Where limestone has been applied there is usually more or less increase in average yields. The beneficial effect is much more pronounced in the residues than in the manure system, the annual acre-returns in the two systems being $4.56 and $11.94 respectively. From a detailed study of the records it would

TABLE 9.—ALEDO FIELD: SOME FINANCIAL RESULTS BASED ON CROP YIELDS FOR THE ROTATION PERIOD ENDED IN 1930

Figures indicate average annual acre-values

Untreated land, acre-value of *all crops*	$30.29
Acre-value of *crop increase* from—	
Manure, alone	$ 7.99
Residues, alone	2.96
Limestone, used with manure	4.56
Limestone, used with residues	11.94
Rock phosphate, used with manure and limestone	.53
Rock phosphate, used with residues and limestone	.92
Potash, used with residues, lime, and rock phosphate	1.97
Net acre-value of *crop increase* under most profitable treatment—	
In livestock system (manure, limestone)	$ 7.76
In grain system (residues, lime)	12.86
Net acre-value of total crops under most profitable treatment—	
In livestock system (manure, limestone)	$38.37
In grain system (residues, limestone)	43.30

appear, as might be expected, that an increasing response to limestone is developing as the work progresses.

Rock phosphate as used in these experiments has not been profitable, whether applied with manure or with residues. The gains in yield as measured by the acre-value of crop increases—53 cents in the manure system and 92 cents in the residues system—are by far too small to cover the expense of application with the cost of rock phosphate figured at $15 a ton. However, the economic story has not all been told, for the application of phosphate as well as of limestone has been discontinued in order to observe the residual effects. The results of the next few years, therefore, will be awaited with great interest.

For the effect of potassium, Plots 8 and 9 should be compared. No significant response appears from this treatment, so far as these common field crops show. The present annual acre-return of $1.97 would not justify the purchase of potash fertilizer for use in this kind of farming.

The most profitable of the eight systems of treatment compared, as measured by the effects produced during the last crop rotation period, has been manure and limestone as a livestock system and residues and limestone as a grain system. Taking into account the cost of treatment, the manure-limestone combination has produced crop increases valued at $7.76 an acre a year net, and the residues-limestone combination has produced increases worth $12.86 an acre a year.

In this connection it should be borne in mind that the response to the respective treatments is subject to change as time goes on, so that what is now the most profitable treatment may be superseded by some other treatment in the future.

HARTSBURG FIELD

The results of the Hartsburg field, situated in Logan county just east of the town of Hartsburg, are suggestive of the treatments that should be effective on certain soil types in Fulton county, particularly Black Clay Loam and Black Clay Loam On Drab Clay described on page 13.

Work on the Hartsburg field was started in 1911. The field is laid off in five series of 10 plots each. The crop rotation up to 1923 was wheat, corn, oats, and clover, with alfalfa growing on a fifth series.

The crops were handled mainly as described on pages 21 and 22 until 1918, when it was planned to remove one hay crop and one seed crop of clover from the residues plots. In 1921 it was decided to harvest all the clover as hay. At that time the return of the oat straw to the land was discontinued. In 1922 the return of the wheat straw was likewise discontinued. The application of limestone was discontinued in 1922 after amounts ranging from 7½ to 10 tons an acre on the different series had been applied, and no more will be added until further need for it becomes apparent. In 1923 the phosphate applications were evened up to a total of 4 tons an acre on all phosphate plots, and no more will be applied for an indefinite period. At that time the rotation on the first four series was changed to corn, corn, oats, and wheat with a seeding of hubam clover in the oats on all plots, and a seeding of biennial sweet clover in the wheat on the residues plots. The rotation was changed also on the fifth series to corn, oats, wheat, and a mixture of alfalfa with red clover. The soil treatments are as indicated in Table 10, which summarizes by crops the yields for the period during which the plots have been under full treatment. Table 11 records some interesting figures derived from a study of the results of the last crop rotation period.

The outstanding feature of the results on the Hartsburg field is the large increases produced by organic manure whether in the form of crop residues or stable manure. Residues alone, however, are more effective in producing increased yields than is manure alone, as shown in Tables 10 and 11. This peculiar behavior is probably related to the fact that sweet clover, which is such an essential factor in the residues system, grows well on this soil without the aid of applied limestone. This lack in effectiveness of limestone becomes evident on

TABLE 10.—HARTSBURG FIELD: GENERAL SUMMARY OF CROP YIELDS
Average annual crop yields 1913-1930—bushels or (tons) per acre

Serial plot No.	Soil treatment	Wheat *16 crops*	Barley *1 crop*	Corn *28 crops*	Oats *19 crops*	Clover *8 crops*	Soy-beans *2 crops*	Alfalfa *8 crops*
1	0	25.1	35.4	45.3	47.2	(1.86)	(1.29)	(3.47)
2	M	28.3	44.2	55.3	52.1	(2.21)	(1.64)	(3.67)
3	ML	34.0	50.0	62.7	57.2	(2.35)	(1.82)	(3.91)
4	MLP	35.8	50.0	61.6	56.8	(2.43)	(1.92)	(4.19)
5	0	28.0	42.7	50.0	46.6	(1.66)	25.8	(3.33)
6	R	31.0	47.5	61.8	52.5	(2.00)	26.8	(3.78)
7	RL	28.7	53.3	65.9	50.9	(1.99)	28.4	(3.45)
8	RLP	33.3	46.9	66.1	54.7	(2.04)	26.1	(4.04)
9	RLPK	33.3	55.6	63.9	54.1	(1.99)	26.4	(4.16)
10	0	29.6	45.8	50.9	47.2	(2.09)	(1.69)	(3.20)

TABLE 11.—HARTSBURG FIELD: SOME FINANCIAL RESULTS BASED ON CROP YIELDS FOR THE ROTATION PERIOD ENDED IN 1930
Figures indicate average annual acre-values

Untreated land, acre-value of *all crops*	$25.38
Acre-value of *crop increase* from—	
Manure, alone	$ 4.11
Residues, alone	7.28
Limestone, used with manure	5.82
Limestone, used with residues	1.58
Rock phosphate, used with manure and limestone	−.43
Rock phosphate, used with residues and limestone	1.67
Potash, used with residues, lime, and rock phosphate	−.39
Net acre-value of *crop increase* under most profitable treatment—	
In livestock system (manure, limestone)	$ 6.06
In grain system (residues, lime)	6.85
Net acre-value of *total crops* under most profitable treatment—	
In livestock system (manure, limestone)	$30.04
In grain system (residues, limestone)	31.42

comparing the returns from Plot 3, manure and limestone, with Plot 7, residues and limestone.

Rock phosphate, altho having shown some benefit to the wheat crop, has on the whole not been profitable. In the manure system the value of crop increases produced by phosphate appears on the negative side as minus 43 cents an acre, and in the residues system the value $1.69 is far short of the cost of treatment. As a matter of fact, the test for available phosphorus mentioned on page 43 indicates an abundant supply of this plant food already present in the soil.

Potassium is another element which is apparently not needed in growing the ordinary field crops on this kind of land. In combination with residues, lime, and phosphate, potassium has shown no significant effect on any crop except one barley crop. The average annual acre-value of the crop increases produced by potash appears in the record as minus 39 cents.

Thus it appears from these various comparisons that the most profitable treatment under the livestock system of management on the Hartsburg field is manure and limestone, which has given a net acre-return of $6.06 in increased yields. Without manure, the most profitable treatment is now the residues-limestone combination, which is giving a net return in increased yields of $6.85.

A close study of the history of these plots reveals the fact that the need for lime is of recent origin. This fact illustrates a principle already pointed out, and that is that under continued cropping soil requirements change. It may therefore happen that some other combination will at some time in the future pay better than this one.

APPENDIX

PRINCIPLES OF SOIL MANAGEMENT

Clear thinking on the complex problems of soil management must start with a realization that there are many different kinds of soils, each differing from the others in soil characters. The fertilizer, management, and cropping requirements of each kind of soil are not yet fully worked out, altho knowledge regarding the agricultural significance of the various soil types recognized in the soil survey is rapidly accumulating.

Soils are dynamic, exceedingly complex, natural bodies made up of organic and inorganic materials and teeming with life in the form of microorganisms. Because of these characteristics, soils cannot be considered as reservoirs into which given quantities of an element or elements of plant food can be poured with the assurance that they can be expected to respond uniformly to a given set of management standards. To be productive a soil must be in such condition physically with respect to structure and moisture as to encourage root development; and in such condition chemically that injurious substances are not present in harmful amounts, that a sufficient supply of the elements of plant food become available or usable during the growing season, and that lime materials are present in sufficient abundance to favor the growth of higher plants and of beneficial microorganisms.

It is obvious that in order to fulfill these conditions no single system of soil treatment can be laid down for all situations. The long-time records from numerous soil experiment fields scattered over Illinois demonstrate strikingly that different soils require different management practices. Some soils are naturally so productive that no fertilizer treatment yet tried has succeeded, on a paying basis, in raising the crop yields over their natural capacity. On the other hand, there are other soils so poor that altho under proper treatment the yield can be increased many fold, the plane of production under the best management known is still so low that it is questionable whether it pays to farm the land at all. Between these two extremes all grades of productivity are found. A further significant fact brought out in a study of these experiment fields is that a given piece of land seldom responds to soil treatments in the same manner thruout its history. The most efficient treatment during one rotation period does not necessarily remain the most efficient in another period.

Thus it appears that soil management is a complex matter even when considered from only one side of the problem, namely, that of producing crops. In addition to these complexities connected with production, however, are those having to do with the everchanging economic conditions by which market prices are affected. Whether a certain yield produced by a given soil treatment will be profitable depends directly upon the price of produce as well as upon the cost of the treatment, and every farmer knows only too well something of the violent fluctuations in market prices that have taken place in recent years. Furthermore, costs of fertilizing materials change from time to time, and these changes do not necessarily run parallel with the fluctuations in value of farm products.

With these facts in mind it is not difficult to understand that, from the standpoint of financial profits, a soil-management practice perfectly recommendable this year may become wholly unprofitable in another year and, vice versa, a practice that is unprofitable under present conditions may become highly profitable at another time.

The above remarks suggest something of the difficulty of prescribing definite recommendations for specific soil treatments and of the futility of making blanket recommendations to cover the requirements of all soils and all crops at all times. In mentioning these difficulties there is no intention to discourage efforts at planning programs of soil improvement; the purpose, rather, is to set forth some of the uncertainties involved and, in particular, to warn against hasty conclusions based upon scanty experience or superficial observation.

In spite of the many complexities involved in the problem of soil improvement, there are certain broad, underlying principles that are basic and that must be taken into consideration in laying out any improvement program. Underlying the permanent and profitable productivity of the soil is the maintenance of good physical condition, favorable biological activity, a suitable soil reaction, and an adequate supply of available plant-food elements during the growing season. The chief practices which accomplish these ends are—

1. Adequate drainage
2. Protection from erosion
3. Application of limestone where necessary
4. A good cropping system, including suitable legumes for soil improvement
5. Provision for active organic matter by returning regularly animal and plant manures
6. Purchase of mineral plant-food elements to supply deficiencies

PROVIDING ADEQUATE DRAINAGE

Adequate drainage is recognized as essential for the consistent production of satisfactory crops. Crops vary, however, in their ability to endure poor drainage. Alsike clover, for example, is better adapted to wet land than is red clover. Some bottom lands produce excellent summer crops but cannot be used for winter crops because of flooding. Altho such lands may not be well drained, it is often possible to raise good crops of corn on them year after year, because, as a result of frequent overflow, they receive periodically a fresh deposit of soil material. Such a practice on poorly drained upland would not be feasible. Upland soils, with few if any exceptions, require a well-planned cropping system if they are to be utilized most efficiently, and such a system is difficult to follow unless adequate drainage is provided.

Soils differ in permeability and consequently in their response to the installation of tile. There are soils in the southern and southwestern parts of Illinois, occupying a large total area, which cannot be drained successfully with tile because they have an impervious, clay-pan subsoil. In the east-central part of the state there is a soil occupying a considerable area which does not underdrain well because of an impervious glacial drift which comes to within 30 inches or less of the surface.

The soils of Illinois may well be artificially underdrained with the exception of those noted above. The soils which cannot be underdrained must be drained by means of open ditches and furrows or by means of a combination of open ditches, furrows, and tile provided with manholes thru which the water may enter the tile. In some soils the efficiency of the tile may be greatly increased by starting to fill the tile ditches with top-soil instead of with the more impervious material taken from the bottom of the ditches.

There are some soils in Illinois that cannot be satisfactorily drained either by tile or by open ditches. There should be no attempt to utilize such soils for general farming purposes.

PROTECTING SOIL FROM EROSION

The erosion problem is a serious one in Illinois. We are accustomed to think of erosion as being harmful only on rough and strongly rolling land. This seems, however, to be far from the truth.

The land surface subject to erosion in Illinois might be considered to include three groups of soils based on steepness of slope. The first group might be characterized as being subject to destructive erosion. Land of this character is located, for the most part, adjacent to streams and comprizes a total area in the state of some 7,000 square miles. Land subject to destructive erosion, is for the most part unsuited to general farming. If used for this purpose, erosion is so difficult to control that the returns do not justify the expense involved. Some of the land of this character may be used for orcharding and some of it may be used for permanent pasture but a large proportion of it is suitable only for timber.

A second group of erodible soils may be considered to include land suitable, under proper protection, for permanent pasture and orcharding but unsuited to general farming because of the steepness of the slopes resulting in destructive erosion if tilled. Land of this general character includes some 8,000 square miles. Terracing is recommendable on land of this character as affording a relatively inexpensive and an effective means of reducing erosion. There will be times however, when erosion will be severe on land of this general character even on fields where the best known methods of control are being used.

Generally speaking the two groups mentioned above comprize land of relatively low agricultural value, as this term is commonly understood. If, however, certain of these soils are used for purposes for which they are adapted, they may be of considerable or, in some cases, of high value.

A third group comprizes the gently rolling to rolling land thruout the northern two-thirds of the state. Some 25,000 square miles may be included in this group. This land has a high value for general farming but is subject to harmful erosion and much of it is being seriously damaged thru the removal of surface soil by running water. The erosion problem presented by this third group is probably of more serious concern than that presented by either of the other two because of the high value of the land involved. Erosion can be controlled on a large proportion of this land by means of a good cropping system. Provision should be made for a protecting cover of vegetation particularly in the fall and spring. Cornstalks rolled down at a right angle to the slope are very effective in

FIG. 5.—PROPER SOIL TREATMENT AND CROPPING WOULD HAVE PREVENTED THIS CONDITION
This abandoned hillside is just over the fence from the field shown in Fig. 6.

reducing erosion on this gently sloping land. Long shallow draws may often be kept in permanent sod to great advantage. Broad base terraces may be effectively used where the slope is a little too steep for effective control to be secured with a good cropping system only. It is surprising however how effective a good cropping system is in decreasing washing. Experimental results indicate that on relatively gentle slopes of about 4 percent the surface seven inches of soil may be washed off in about twenty-five years where a poor cropping system is used, and that the use of a good cropping system alone will extend the time for the removal of the same amount of soil to some 350 years.

The method or combination of methods suitable for the control of erosion on any given area depends on many factors; that is to say, no generally applicable,

FIG. 6.—CORN GROWING ON IMPROVED HILLSIDE OF THE VIENNA EXPERIMENT FIELD
This land had formerly been badly eroded. It was reclaimed by proper soil treatment and cropping. Compare with Fig. 5.

detailed directions for controlling erosion can be given because such important factors as steepness of slope, length of slope, and permeability of the soil must be taken into consideration.

A detailed discussion of methods of controlling erosion will be found in Bulletin 207, "Washing of Soils and Methods of Prevention," and Circular 290, "Saving Soil by Use of Mangum Terraces," published by this Station.

APPLYING LIMESTONE TO CORRECT ACIDITY

The maintenance of a favorable soil reaction has been mentioned as one of the essentials in a rational system of soil management, and in contemplating a soil-improvement program one of the first steps for consideration is the application of limestone.

In considering the use of limestone it should be understood that this material functions in several different ways, and that a beneficial result may therefore be attributable to quite diverse causes. Limestone provides calcium, a plant-food element for which certain crops have a high requirement. It corrects acidity of the soil, thus making for some crops a much more favorable environment as well as establishing conditions absolutely required for some of the beneficial bacteria. It plays an essential role in the chemical transformation of nitrogen. It helps to check the growth of certain fungous diseases, such as corn root rot. Experience indicates that it modifies either directly or indirectly the physical structure of fine-textured soils, frequently to their great improvement. Most important of all its properties is its power to neutralize soil acidity, thus making possible thru the growing of legumes the reclamation of millions of unproductive acres as well as the improvement of land of moderate or even high productive capacity.

Soils vary tremendously with respect to acidity, and the question arises as to how the farmer is to know whether his land needs limestone. Much information on this subject, as it pertains to Illinois land, is to be found in connection with the soil survey. Some soil types are uniformly acid, and therefore in their description attention is called to the necessity of applying limestone; other types being alkaline thruout, do not need lime, and in the discussion this fact is recorded. There are, however, extensive soil types in which the lime requirement is not uniform. It may vary from field to field on the same farm. It may even change on a given field with the passing of time, especially under heavy cropping. Obviously in such cases a definite recommendation in regard to liming cannot be given, and under these circumstances the farmer is advised to resort to a test which he himself can learn to make.

Any citizen of the state may obtain from the county farm adviser or from the Experiment Station instructions for making a systematic limestone map of his fields, showing not only the areas that need liming but also approximately the amount of limestone to apply. Such a test made on soils where the lime requirement is decidedly variable is saving many hundreds of dollars in expenditures for limestone where limestone is not needed, as well as preventing the waste of clover seed on soils too acid to grow clover. For a description of this test see Circular 346 of this Station, "Test Your Soil for Acidity."

A good indication as to whether a soil needs limestone is the character of the growth of certain legumes, particularly sweet clover. This crop does not thrive on acid soils and its thrifty growth therefore indicates that the soil is not acid, at least in a harmful degree. Some legumes, for example red clover, will grow fairly well on soil of moderate acidity provided conditions are otherwise favorable. Too much reliance therefore should not be placed on the behavior of

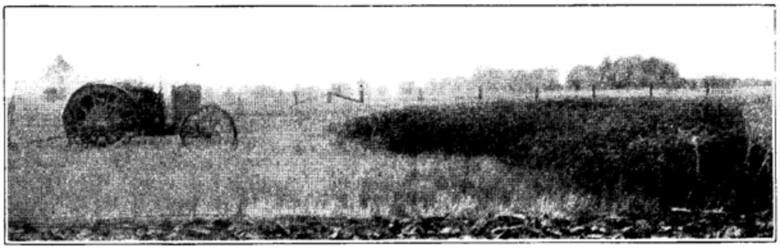

FIG. 7.—SWEET CLOVER AS AN INDICATOR OF THE NEED FOR LIMESTONE
Left, no limestone; right, limestone. Sweet clover is one of the crops most sensitive to soil acidity. This crop will not grow on acid soils until limestone has been applied.

legumes as an indicator of the need of liming, for it frequently happens that fair stands are mistaken for good stands and even good yields can often be greatly increased by the use of limestone. Therefore it is well to be definitely informed regarding the condition of the soil with respect to acidity, using, where necessary, a reliable test such as that mentioned above.

MAINTAINING A WELL-PLANNED CROP ROTATION

In any program of permanent soil improvement one should adopt at the outset a good system of crop rotation, including a liberal use of legumes. It is impossible to prescribe the best rotation for every individual case because what will prove to be the most advantageous system to follow depends upon a number of different factors. Of primary importance among these factors is the location of the farm with respect to soil, to climate, and to market. The particular rotation to be followed will be determined further by the type of farming—whether grain, livestock, orcharding, or other kind of enterprise. Finally, not the least important to be considered are the personal interests and inclinations of the farmer himself.

Following are a few suggested rotations, applicable mainly to the corn belt, which are intended to serve merely as patterns or outlines, to be modified according to special circumstances. In these suggested rotation programs the more common crops are mentioned merely as types, for which other crops of similar nature may be substituted as desired. In the following lists, for example, oats may be replaced by barley or spring wheat, and likewise winter rye might take the place of winter wheat. Or it may be advisable in some cases to divide the acreage of small grain and raise different kinds; for example, plant a part of the land to oats and a part to barley. The word "clover" in the following lists of rotations is used in a general sense to designate red, alsike, or sweet clover, or even a clover-grass mixture to serve either as pasture or meadow. In the event

of clover failure soybeans may be substituted. The value of sweet clover, especially as a green manure, for building up depleted soils is becoming thoroly established, and its importance in a crop-rotation program may well be emphasized. In the following lists the word "clover" in parentheses signifies that clover is seeded in the grain crop.

Numberless different cropping systems might be enumerated, ranging thru various long-term and short-term rotations, but it will suffice for the present purpose to mention only a few systems as suggestive of types of rotations.

Six-Year Rotations

Among the longer type of rotations the following six-year systems are suggested as being good practical rotations adaptable under many circumstances. Two such programs are presented, one in which corn predominates and the other in which wheat is the major crop. Following are the crop sequences:

System A	*System B*
Corn	Corn
Corn	Oats
Oats (clover)	Wheat (clover)
Clover	Clover
Wheat (clover)	Wheat (clover)
Clover	Clover

In grain farming most of the crop residues are returned to the soil and the clover may be left on the land or returned after threshing out the seed. In livestock farming the clover may be mixed with alfalfa or with timothy, the crop being used for pasture or for meadow as desired. Soybeans, a crop that is rapidly coming into favor, can be introduced into System A by replacing either the first or the second corn crop or the last clover crop. In System B perhaps the best place for soybeans would be following the second wheat crop, altho it is possible to grow them in place of the oats.

An objection sometimes arises to wheat following clover on account of the wheat lodging. This lodging is not so likely to happen when the clover is cut as hay and removed from the land.

Five-Year Rotations

A five-year rotation system offers one of the most convenient cropping plans that can be devised for general farming. It is flexible, it provides diversification, and it can be made to give large place to legumes.

Here, three different basal systems are presented. Systems C and E are designed for corn as the major crop while System D is intended to give large place to wheat growing.

System C	*System D*	*System E*
Corn	Corn	Corn
Corn	Oats	Corn
Oats (clover)	Wheat (clover)	Soybeans
Clover	Clover	Oats (hubam)
Wheat (clover)	Wheat (clover)	Wheat (sweet clover)

It is of interest to observe in System C that if soybeans were to replace second-year corn, and the clover catch crop were allowed to grow awhile in the

spring before corn planting, then a legume crop would appear on every acre every year. The same provision could be effected in System D by replacing the oats with soybeans.

A growing problem on many farms where little livestock is fed is the economical disposal of the clover crop. A farmer can ill afford to give up a considerable portion of his land every year to clover production when he can neither feed nor sell the crop. In order to solve this problem the rotation mentioned as System E is proposed. The hubam is an annual sweet clover which seeded in the oats makes a heavy growth to plow down in preparation for the wheat and this, together with the biennial sweet clover grown in the wheat the following year, should furnish plenty of leguminous growth to maintain the rotation, leaving all the land free every year for a cash crop.

Four-Year Rotations

The four-year rotation represents a rather common cropping system. Among the several possibilities the following are suggested as practical programs for a four-year rotation:

System F	*System G*	*System H*
Corn	Corn	Corn
Corn	Oats	Corn
Oats (clover)	Wheat (clover)	Oats (hubam)
Clover	Clover	Wheat (sweet clover)

System F which calls for half the land to be in corn, requires a productive soil. However, half the land is under legumes and this is also true of System G. Soybeans might take the place of one of the corn crops in Systems F and H. In System G they might take the place of the oats provided the bean crop is removed early in order to make way for the fall seeding of the wheat.

System H is proposed in order to accomplish the same purpose in a four-year rotation as System E in the five-year program, namely, to provide for a salable crop on all fields every year.

Three-Year Rotations

One of the most common rotations practiced in the corn belt is the three-year crop succession of corn, oats, and clover (System I). From the standpoint of soil maintenance this is a good rotation. Legumes appear on the land two years out of three. It is also advantageous from the standpoint of labor economy, for plowing is required only once in three years. Its main disadvantage perhaps lies in the restricted crop diversification.

System I	*System J*
Corn	Wheat (clover)
Oats (clover)	Corn
Clover	Soybeans

An opportunity to introduce wheat into a three-year cropping plan is offered in System J. It is of interest to note that by seeding a catch crop of sweet clover in the wheat, to be plowed under the following spring just before corn planting, the land is under legumes some portion of the season every year. It will be necessary to harvest the soybeans early either by using an early variety

or by cutting for hay in order to prepare the land for winter wheat. In some regions it may be desirable to substitute cowpeas for the soybeans.

Two-Year Rotation

The well-known practice of alternating corn and oats has long been pointed out as an example of a bad rotation under which thousands of corn-belt farms are headed toward ruination. However, with the advent of sweet clover, that great soil restorer, a corn-oats rotation becomes a practical possibility.

System K

Corn
Oats (sweet clover)

In this system sweet clover is sown in the oats, pastured in the fall and the following spring if desired, and then plowed down in preparation for corn. From the standpoint of soil upkeep, this cropping plan, which may fit well in certain situations, is offered as an interesting possibility, altho from the general farm-management point of view it may lack some of the advantages of the longer rotations described above.

Altho oats are mentioned as the spring grain crop, as a matter of fact, by dividing the land devoted to small grain and introducing barley, these two crops can be grown simultaneously, thus providing a three-crop system in a two-year cycle.

Alfalfa and Pasture in Rotation

Alfalfa is a highly desirable crop to grow, especially in livestock farming. Its use as a biennial legume in the rotation may well be recommended. It is often desirable, however, to include alfalfa as a perennial stand in the cropping system. This can be done by providing one extra field. The alfalfa occupies a field during a complete rotation period of the other crops plus one year extra. The alfalfa is then shifted to another field while the other crops rotate, and so on around the entire field system.

It may be observed that this same plan for alfalfa in rotation will provide for continuous pasture of any kind, either of perennial grass—redtop, for example, in southern Illinois—or of grass and clover mixture.

SUPPLYING RIGHT KINDS AND AMOUNTS OF ORGANIC MATTER

Organic matter acts beneficially chiefly in two ways: it helps to maintain favorable physical conditions in the soil; and it supplies food material for the microscopic organisms which inhabit the soil and which in turn, thru their life processes, effect many of the necessary chemical transformations that render plant food available for the growing crops.

The main sources of supply for organic matter are stable manure, crop residues, and green manures.

A recent study of the results from the soil experiment fields located in many different parts of Illinois reveals the fact that the system of treatment that has most frequently returned the greatest profit is manure with limestone. Of the eight systems compared, this proved to be the winning treatment on more than

half the fields. This fact indicates the very great value of stable manure and suggests the importance of its careful conservation and use on every farm where this material is available. On most farms, however, there is not sufficient animal manure produced to cover the land, and thus it becomes necessary to resort to some other supply of organic matter. The alternative here lies in the so-called "crop-residues" system, in which unused materials such as stalks, straw, and chaff are returned to the land and plowed under along with leguminous green-manure crops.

In connection with the application of organic matter, an important distinction between kinds of organic matter with respect to chemical make-up has come to be recognized within the last few years. It is commonly observed that an excessive application of straw or similar material is likely to produce a depression in crop growth which may result in lowering the yield. In addition to the unfavorable physical effect of plowing down a mass of decay-resistant material, particularly if dry weather ensues, a detrimental chemical effect may also follow. The large quantity of cellulose contained in straw stimulates the activities of a certain set of microscopic organisms. These may become so active as actually to compete with the growing plants for nitrate and so under certain circumstances to cause nitrogen hunger. Good judgment must therefore be exercised in applying strawy material. Heavy applications should ordinarily be avoided unless they can be plowed under with a good growth of legumes or else applied at such a time as not to interfere with a crop having a large nitrate requirement.

PLANT-FOOD REQUIREMENTS AND SUPPLY

Ten chemical elements have long been accepted as being essential for the growth of the higher plants. These are carbon, hydrogen, oxygen, nitrogen,

TABLE 12.—PLANT-FOOD ELEMENTS IN COMMON FARM CROPS[1]

Produce		Nitrogen	Phosphorus	Sulfur	Potassium	Magnesium	Calcium	Iron
Kind	Amount							
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Wheat, grain	1 bu.	1.42	.24	.10	.26	.08	.02	.01
Wheat straw	1 ton	10.00	1.60	2.80	18.00	1.60	3.80	.60
Corn, grain	1 bu.	1.00	.17	.08	.19	.07	.01	.01
Corn stover	1 ton	16.00	2.00	2.42	17.33	3.33	7.00	1.60
Corn cobs	1 ton	4.00	....	....	4.00	....	....	....
Oats, grain	1 bu.	.66	.11	.06	.16	.04	.02	.01
Oat straw	1 ton	12.40	2.00	4.14	20.80	2.80	6.00	1.12
Clover seed	1 bu.	1.75	.50	....	.75	.25	.13	....
Clover hay	1 ton	40.00	5.00	3.28	30.00	7.75	29.25	1.00
Soybean seed	1 bu.	3.22	.39	.27	1.26	.15	.14	....
Soybean hay	1 ton	43.40	4.74	5.18	35.48	13.84	27.56	....
Alfalfa hay	1 ton	52.08	4.76	5.96	16.64	8.00	22.26	....

[1]These data are brought together from various sources. Some allowance must be made for the exactness of the figures because samples representing the same kind of crop or the same kind of material frequently exhibit considerable variation.

phosphorus, sulfur, potassium, calcium, magnesium, and iron. To this list certain other elements have been added from time to time as being either necessary in the physiological processes or else present merely on account of absorption from the soil solution.

Of the elements of plant food, three (carbon, oxygen, and hydrogen) are secured from air and water, and the others from the soil. Nitrogen, one of the elements obtained from the soil by all plants, may also be secured indirectly from the air by the class of plants known as legumes, in case the amount liberated from the soil is insufficient.

Table 12 shows the average content of some of our most common field crops with respect to seven important plant-food elements furnished by the soil. The figures show the weight in pounds of the various elements contained in a bushel or in a ton, as the case may be. From these data the amount of an element removed from an acre of land by a crop of a given yield can easily be computed.

The vast difference with respect to the supply of these essential plant-food elements in different soils is well brought out in the data of the Illinois soil survey. It has been found, for example, that the nitrogen in the surface 6⅔ inches, which represents the plowed stratum, varies in amount from 180 pounds an acre to more than 35,000 pounds. In like manner the phosphorus content varies from about 320 to 4,900 pounds, and the potassium ranges from 1,530 to about 58,000 pounds. Similar variations are found in all of the other essential plant-food elements of the soil. In presenting these figures it is not intended

TABLE 13.—PLANT-FOOD ELEMENTS IN MANURE, ROUGH FEEDS, AND FERTILIZERS[1]

Material	Pounds of plant food per ton of material		
	Nitrogen	Phosphorus	Potassium
Fresh farm manure	10	2	8
Corn stover	16	2	17
Oat straw	12	2	21
Wheat straw	10	2	18
Clover hay	40	5	30
Cowpea hay	43	5	33
Alfalfa hay	50	4	24
Sweet clover (water-free basis)[2]	80	8	28
Dried blood	280	.....	.....
Sodium nitrate	310	.....	.....
Ammonium sulfate	400	.....	.....
Raw bone meal	80	180	.....
Steamed bone meal	20	250	.....
Raw rock phosphate	.....	250	.....
Superphosphate	.....	125	.....
Potassium chlorid	.....	.....	850
Potassium sulfate	.....	.....	850
Kainit	.....	.....	200
Wood ashes[3] (unleached)	.....	10	100

[1]See footnote to Table 10. [2]Young second-year growth ready to plow under as green manure.
[3]Wood ashes also contain about 1,000 pounds of lime (calcium carbonate) per ton.

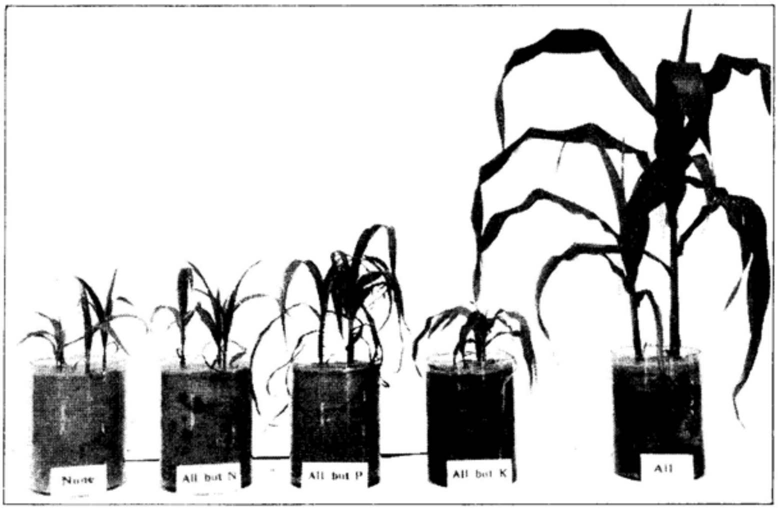

FIG. 8.—ALL ESSENTIAL PLANT-FOOD ELEMENTS MUST BE PRESENT

The jars in which these corn plants are growing contain pure sand to which have been added various combinations of the essential plant-food elements. If a single one of these elements is omitted, the plants cannot develop; they die after the small supply stored in the seed becomes exhausted.

to imply that plants are restricted in their feeding to the surface stratum, nor that the total quantities of the various plant-food elements give a reliable indication of the immediate fertilizer requirements of a soil except in extreme cases. Such extreme cases, however, are relatively rare and there are the great middle classes in which chemical composition varies so little as to furnish no clue whatever to the probable effect of a particular fertilizer treatment. Much depends upon the ability of the crops grown to utilize plant-food material, and much depends upon the solubility of the plant-food substances themselves. When an element becomes so reduced, either in total quantity or in available form, as to become a limiting factor of production, then we must look for some outside source of supply. Table 13 shows the approximate quantities of some of the more important plant-food elements contained in materials most commonly used as fertilizers.

Nitrogen Problem

The nitrogen problem is one of foremost importance in American agriculture. There are four reasons for this: nitrogen is becoming increasingly deficient in most soils; its cost, when purchased on the open market, is often prohibitive; it is removed from the soil in large amounts by crops; and it is readily lost from soils by leaching. A 50-bushel crop of corn requires about 75 pounds of nitrogen for its growth; and the loss of nitrogen from soils by leaching may vary from a few pounds to over one hundred pounds an acre in a year, depending upon the treatment of the soil, the distribution of rainfall, and the protection afforded by growing crops.

An inexhaustible supply of nitrogen is present in the air. Above each acre of the earth's surface there are about 69 million pounds of atmospheric nitrogen.

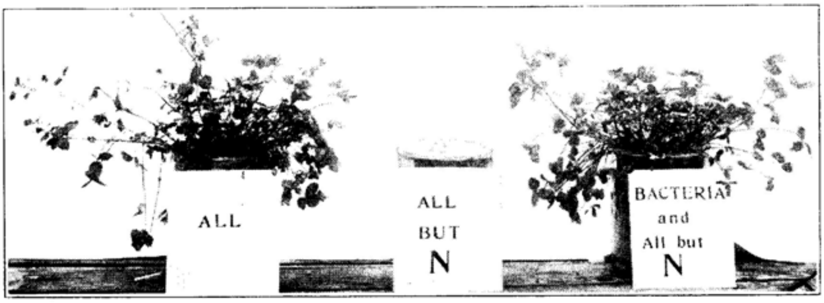

FIG. 9.—LEGUMES CAN OBTAIN THEIR NITROGEN FROM THE AIR

The photograph tells the story of how clover benefits the soil. In the pot at the left all the essential plant-food elements, including nitrogen, are supplied. In the middle jar all the elements, with the single exception of nitrogen, are present. At the right nitrogen is likewise withheld but certain bacteria are supplied that enable the clover to secure nitrogen from the air.

Leguminous plants such as the clovers are able, with the aid of certain bacteria, to draw upon this supply of air nitrogen, utilizing it in their food requirements. In so doing, these leguminous plants if returned to the land add to the soil a part of the nitrogen which has been taken from the air and transformed into food material that can be assimilated by other kinds of crops that follow. By taking advantage of this fact and introducing periodically into the rotation system a crop of legumes, the farmer may draw upon this cheapest source of nitrogen for soil improvement. Therefore, in general farming, that is, in the production of such crops as corn, oats, wheat, and hay, legumes should furnish the main stock of nitrogen, this stock to be supplemented, of course, by all available manure and by other farm waste materials containing nitrogen.

In addition to these home sources of nitrogen supply, there are various commercial products containing nitrogen offered on the market. These materials formerly consisted largely of sodium nitrate, a mineral imported from South America; ammonium sulfate, produced in the manufacture of coal gas and coke; and certain waste and by-product materials mainly of organic composition. Within very recent time, however, tremendous developments in the synthetic production of nitrogen compounds from air nitrogen have taken place. Among these new fertilizer materials may be mentioned cyanamid, calcium nitrate, sodium nitrate, ammonium nitrate, and urea.

These developments in the artificial fixation of nitrogen will doubtless have a far-reaching effect in reducing the cost of commercial nitrogenous fertilizers. What the limits may be in this direction one dare not predict. Whether these manufactured nitrogen compounds will become so cheap some day as actually to compete with legume nitrogen is problematical, especially when the other advantages offered by legumes are considered. However, the day has not yet arrived when we can afford to dispense with legumes as a green manuring crop in the production of grain and hay.

Accepting, then, this principle that legumes and farm wastes must constitute the main source of nitrogen supply, the question arises—can these home-grown materials be supplemented to advantage by the use of commercial carriers of nitrogen?

The impossibility of making blanket recommendations has already been pointed out. The question finally resolves itself into a matter of expense and profit for each individual case. Sodium nitrate is purchased on the market at present at about $65 a ton. If a farmer applies 100 pounds an acre, he provides about two-fifths of an ounce to a hill of corn. A ton would cover 20 acres and the cost would be about $3.25 an acre. Under present prices an increase of about four to five bushels of corn or wheat would be required in order to cover the cost before any profit could be realized.

Under what circumstances might such increases in yield be reasonably expected? It is possible that in many cases where manure or legumes have not been used, such an application of nitrogen would return a profit, but such usage should be regarded as a temporary expedient rather than a permanent practice in soil management. Under adverse weather conditions, when soil nitrates are formed too slowly or are washed away by excessive rain, an application of nitrogen fertilizer may prove highly beneficial to wheat and corn.

A peculiar hazard accompanies the application of nitrogen that does not obtain in applying phosphate or potash. Nitrates are readily washed away, and if circumstances are such that the first crop fails to utilize the nitrogen, little or no residual effect on the following crops can be expected. For this reason special caution should be used against applying excessive amounts of nitrogen. Usually it is well to divide the application of a quickly soluble nitrogen fertilizer such as sodium nitrate, using a portion at planting time and distributing the remainder at a later date. Nitrogenous fertilizers are often made up of a mixture of materials whose nitrogen becomes soluble with varying degrees of rapidity, thus automatically distributing the action of the nitrogen over a period of time.

Phosphorus Problem

Different soil types display great variation in phosphorus content and, on the other hand, soils of like total-phosphorus content exhibit great variation in response to phosphate fertilization. The removal of phosphorus by continuous cropping slowly reduces the amount of this element available for crop use unless its addition is provided for by natural means such as overflow, or by agricultural practices such as the addition of farm manure and phosphatic fertilizers and perhaps the use of rotations in which deep-rooting leguminous crops are frequently grown. Results obtained from the soil experiment fields of Illinois show that some soils respond highly to phosphate fertilization, while others give a very low response or none. Reports from county farm advisers and farmers in general are in agreement with these experimental results.

It should be noted that the total quantity of phosphorus in a soil is not a reliable indicator of the probable response to phosphate fertilization. Apparently it is a matter of solubility or the chemical form in which the phosphorus exists rather than total quantity.

A simple field test has recently been devised at the Illinois Experiment Station which will distinguish soils having a high amount of available phosphorus from those having a low amount. Information concerning this test is furnished in Bulletin 337, "A Field Test for Available Phosphorus in Soils."

There are several different phosphorus-containing materials that are used as fertilizers. The more important of these are rock phosphate and superphosphate. Other valuable carriers of phosphorus are bone meal and basic slag.

Rock phosphate is a mineral substance found in vast deposits in certain regions. A good grade of the rock should contain 12 to 15 percent of the phosphorus element. The rock should be ground to a powder fine enough to pass thru a 100-mesh sieve, or even finer. Considerable experimentation in the finer grinding is under way in the hope of increasing the plant-food value of the product and thus make possible a reduction in the amount that it is necessary to apply.

Superphosphate is produced by treating rock phosphate with sulfuric acid. The two are mixed in about equal amounts; the product therefore contains about one-half as much phosphorus as the rock phosphate itself. By further processing, different concentrations are produced. The most common grades of superphosphate now on the market contain 7, 8¾, and 10½ percent of the element phosphorus, and even more highly concentrated products containing as high as 21 percent are to be had. In fertilizer literature the term phosphorus is usually expressed as "phosphoric acid" (P_2O_5) rather than the element phosphorus (P), and the chemical relation between the two is such as to make the above figures correspond to 16, 20, 24, and 48 percent of phosphoric acid respectively. Likewise the 12 to 15 percent of phosphorus in rock phosphate corresponds to 29.5 to 34.3 percent of phosphoric acid. Besides phosphorus, superphosphate also contains sulfur, which is likewise an element of plant food, altho this fact has little agricultural significance for Illinois, where the soils generally are sufficiently stocked with sulfur. In general, phosphorus in superphosphate is considered to be more readily available for absorption by plants than is the phosphorus in raw rock phosphate, altho there is often good response in the crops immediately following the application of rock phosphate.

Obviously the carrier of phosphorus that will give the most profitable returns, considered from all standpoints, is the one to use. The question of which is the most profitable, however, remains unsettled, altho it has been the subject of much discussion and investigation. The fact probably is that there is no single carrier that will prove the most economical under all circumstances because so much depends upon soil conditions, crops grown, length of haul, and market conditions.

The relative cheapness of raw rock phosphate as compared with the treated material, superphosphate, makes it possible to apply for equal money expenditure considerably more phosphorus per acre in the form of rock than in the form of superphosphate, the ratio being, under present market conditions, roughly speaking 3½ to 1; that is to say, a dollar will purchase about three and a half times as much of the phosphorus element in the form of rock phosphate as in the form of superphosphate, and this is an important consideration if one is interested in building up a phosphorus reserve in the soil.

On several of the Illinois soil experiment fields rock phosphate and superphosphate are being compared in systems of management looking toward permanent soil improvement, and are applied in amounts corresponding approximately to equivalent money expenditures. So far as these comparisons show, there

appears to be little consistency in the results. In some years and on some crops superphosphate has furnished the greater profit; in other years and on other crops the reverse is true. In some cases neither material has paid for its cost, indicating that phosphorous is not a limiting factor in production on all soils. On the whole, therefore, if possible residual effects are disregarded, there appears to be no indisputable evidence for general discrimination between the two forms of phosphate.

Potassium Problem

Our most common soils, the silt loams and clay loams, are well stocked with potassium altho it exists mainly in a very slowly soluble form and probably only a very small percentage of the total potassium exists in a form available to plants at any one time.

Many field experiments in various sections of Illinois during the past twenty-five years have shown little or no response to the application of potassium in the production of our common grain and hay crops. On the light-colored soils of southern Illinois, however, where stable manure has not been employed, potassium has been applied with profit, the benefit appearing mainly in the corn crop.

Peat soils usually respond to potash fertilization. The Illinois Experiment Station has demonstrated in field experiments located on peat land that the difference between success and failure in raising crops on such land depends upon the application of a potash fertilizer.

Potassium has proved beneficial also on the so-called ''alkali'' spots occurring on certain soil types that are rather high in organic matter, including peat and dark-colored sandy, silt, and clay loams. The unproductiveness of these soils is probably due largely to the unavailable condition of the soil potassium as well as to an unbalanced condition of the plant nutrients resulting from an excess of nitrate nitrogen. The addition of potash has a beneficial influence upon both of these unfavorable conditions.

Potash fertilizer may be procured in the form of one of the potassium salts, such as the chlorid, sulfate, or carbonate, and any of these materials may be applied, where needed, at the rate of 50 to 150 pounds an acre according to the method of distribution. For our most common crops about the only basis for choosing among these forms is the matter of price, taking into consideration the potassium content.

Kainit is another substance containing potassium, but it is combined with magnesium in the form of a double salt. It is therefore less concentrated than the salts mentioned above, and so should be applied in larger quantities. An application of about 200 pounds or more of kainit to the acre is suggested.

Use of Mixed Commercial Fertilizers

A mixed commercial fertilizer is a combination of substances containing either two or three of the plant-food elements nitrogen, phosphorus, and potassium. If the material contains all three of these elements, it is said to be a ''complete'' mixed fertilizer; if only two of the three are present, it is said to be an ''incomplete'' mixed fertilizer.

A complete mixed fertilizer has the general formula $N-P_2O_5-K_2O$ (nitrogen, phosphorus pentoxid, potassium oxid), the proportions of the elements varying according to the way in which the material is compounded. By substituting figures for the letters in this formula the percentage composition of the fertilizer is indicated. Thus a fertilizer of the formula 5-15-5 contains 5 percent nitrogen, 15 percent phosphorus pentoxid (usually designated as phosphoric acid), and 5 percent potassium oxid (usually called potash). Translated into pounds, this means that a ton of the fertilizer contains 100 pounds of nitrogen, 300 pounds of phosphoric acid, and 100 pounds of potash. For the benefit of those who are accustomed to think in terms of the simple plant-food elements rather than these combinations, it may be explained that the above amounts correspond to 100 pounds of the element nitrogen (N), 131 pounds of the element phosphorus (P), and 83 pounds of the element potassium (K). Changing the formula to read 0-15-5 indicates that no nitrogen is contained in it; 5-15-0 means that no potassium is present; and 5-0-5 indicates that phosphorus is absent.

In compounding these fertilizers, several ingredients carrying a single kind of plant-food element may be used. For example, a portion of the total nitrogen may be furnished by sodium nitrate, while another portion may be carried in dried blood or in ammonium sulfate. In addition to these plant-food materials, fillers and conditioners are often used in such amounts as to make the finished product contain the desired percentage of plant food.

A distinction between what are considered "high-grade" and "low-grade" fertilizers is now being made upon the arbitrary basis of a total of 16 so-called "units of plant food." Thus a 2-8-2 fertilizer carrying 12 units of plant-food would classify as a low-analysis grade. The advantage of using the higher grade products is becoming more and more generally recognized by both consumers and producers of fertilizers. In the latest developments very highly concentrated forms of fertilizers are being produced containing as much as 60 units of plant food. If the economy of production and the agricultural value justify the general use of materials of such high concentration, there should be a great saving in the cost of transportation and handling thru the use of fertilizers of this type.

The question arises repeatedly regarding the employment of mixed commercial fertilizers, and particularly their employment in connection with a basic program of soil improvement built around the use of legumes and limestone where necessary. An important principle to be borne in mind in the use of any fertilizer is represented in the so-called "law of the minimum," that is, that no benefit can result from the application of a given plant-food element unless the need for that element is a limiting factor in plant growth. If, for example, there is already in the soil enough available phosphorus to produce a 40-bushel crop, and the nitrogen supply or the moisture supply is sufficient for only 40 bushels or less, all the phosphorus one might apply would be absolutely ineffective in increasing the yield beyond this 40-bushel limit.

The most serious objection to the indiscriminate use of mixed commercial fertilizers lies in the fact that frequently only one, or perhaps two, of the plant-food elements carried by the fertilizer are actually needed, in which case a useless expense is incurred for the unnecessary element or elements.

This question of the use of commercial fertilizers is exceedingly complicated because so much depends upon numberless conditions of soil and season. We may be able to analyze in part the conditions of the soil, but we are powerless in predicting the conditions of the oncoming season. A given fertilizer may pay a handsome profit this season but on the same field next year may be absolutely without effect, or even detrimental to the crop. That is why it is impossible to make any general statement or to give a blanket recommendation concerning the use of such fertilizers.

The matter finally resolves itself into two questions: cost of material and benefit derived. Fortunately the cost of material can be definitely determined. In order to get an idea of the expense of applying mixed commercial fertilizers, perhaps we cannot do better than to figure the cost per acre based upon the published recommendations and price quotations of a fertilizer company. The following estimates are based upon the recommendations of such a company as given for the dark-colored silt or clay loam soils of Illinois on land having had manure and clover, and the prices are those quoted for the spring of 1929.

Thus, for the corn crop, 150 pounds per acre of a 5-15-5 fertilizer is recommended to be applied in drills or hill-dropped. The price of this fertilizer is quoted at $53.15 a ton, which would make the cost $3.99 per acre. According to an official report, the farm value of corn for December, 1928, in Illinois was 70 cents a bushel. At this rate an increase of 5.7 bushels of corn per acre would be required to cover the cost of the fertilizer, taking no account of the extra expense in applying it.

For spring grains the recommendation is to use a 0-21-9 fertilizer at the rate of 250 pounds an acre if drilled or 400 pounds if broadcast. The price is $45.10 a ton, thus making the cost per acre $5.64 drilled or $9.02 broadcast. If the spring grain were oats, valued at 38 cents a bushel, the increase in yield to cover the cost of fertilizer would have to be nearly 15 bushels an acre in case the fertilizer were drilled; if it were broadcast nearly 24 bushels would be required to pay the cost before any profit would be realized. If instead of oats the spring grain were wheat valued at $1.02 a bushel, the increase in yield necessary to pay for the fertilizer would be 5½ bushels if the fertilizer were drilled and nearly 9 bushels if broadcast. In like manner the recommended application for potatoes is found to cost $13.13 an acre if the fertilizer is drilled and $26.25 if broadcast. The application recommended for pastures and meadows would cost $13.13 an acre.

The above examples afford some idea of the cost of using mixed commercial fertilizers for the production of our common field crops in so far as the prices quoted remain representative. Unfortunately it is impossible to furnish information with the same certainty concerning the profit that is likely to be derived from these fertilizers, for that will depend upon several varying factors, mainly the amount of increase in yield and the price received for it.

What kind of fertilizers will be profitable and under what particular conditions they will pay must be determined mainly on the basis of actual experience. In this connection it should be borne in mind that in all experimental trials great care must be exercised in drawing conclusions. The soil of a farm or even of a

field is seldom perfectly uniform thruout, and differences in yield really due to differences in soil may easily be mistaken for effects of the fertilizer treatment. Therefore small differences in yield should be critically considered before being accepted as significant. It is particularly risky to base conclusions upon the results of a single year, because of peculiar seasonal effects. Never are two seasons exactly alike, and the results of this year may not apply next year. If outstanding effects from fertilizers occur the first year they are tried, such results may be taken as indicative and accepted as a tentative guide for further work, but final conclusions should be withheld until these results are well confirmed in subsequent trials.

To what extent mixed commercial fertilizers can be profitably employed in connection with a basic program of soil improvement is a problem of great consequence. No doubt there are many instances in which such fertilizers may be used with profit, but it is just as certain that in many other instances their use would result in financial loss. Before investing in mixed fertilizers, farmers should carefully consider the cost, which, as explained above, is an item that can be definitely determined. With the investigations now under way, the Experiment Station hopes soon to be in possession of much more definite information than now exists regarding the use, under present-day conditions, of these mixed commercial fertilizers.

List of Soil Reports Published

1 Clay, 1911
2 Moultrie, 1911
3 Hardin, 1912
4 Sangamon, 1912
5 LaSalle, 1913
6 Knox, 1913
7 McDonough, 1913
8 Bond, 1913
9 Lake, 1915
10 McLean, 1915
11 Pike, 1915
12 Winnebago, 1916
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15 Edgar, 1917
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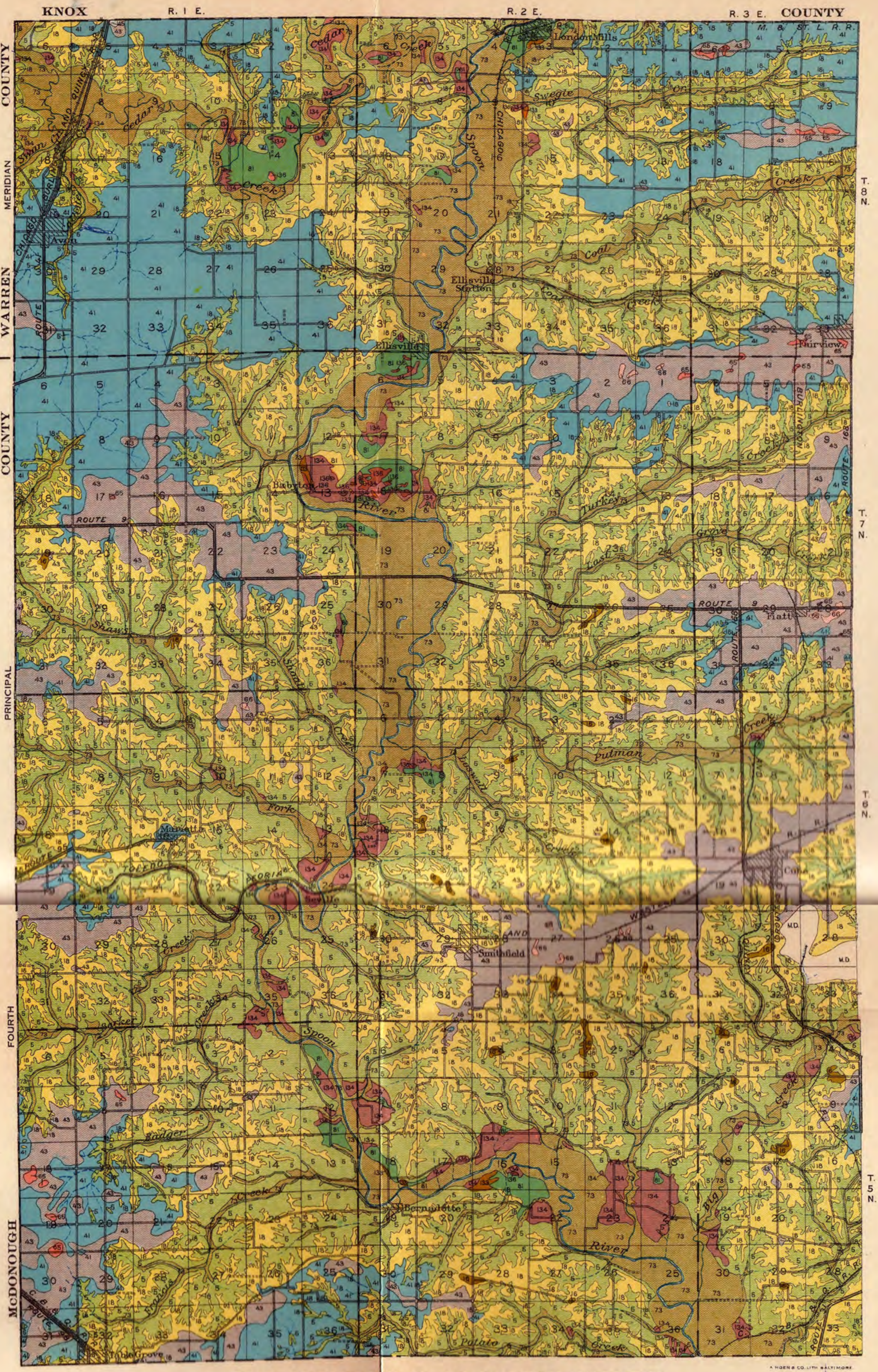
LEGEND

- Eroded Silt Loam
- Brownish Yellow-Gray Silt Loam On Tight Clay
- Brownish Yellow-Gray Silt Loam
- Light Brown Silt Loam
- Brown Silt Loam
- Brown Silt Loam On Clay
- Black Clay Loam
- Black Clay Loam On Drab Clay
- Drab Clay
- Brown Mixed Loam
- Brown Silt Loam Over Sand or Gravel
- Brown Sandy Loam Over Sand or Gravel
- Brownish Yellow-Gray Silt Loam Over Sand or Gravel
- Brown-Gray Silt Loam On Tight Clay Over Sand or Gravel

CONVENTIONAL SIGNS

- Public Roads
- Metalled Roads (gravel—all year)
- Paved Roads
- Private Roads
- Railroads (steam)
- Railroads (electric)
- Township Boundary Lines
- County Boundary Lines
- Levees
- Streams (flowing)
- Streams (intermittent)
- Lakes or Ponds
- Swamps
- Small Areas Limestone Rock Outcrop
- M.D. Mine Dumps

Scale
0 1/4 1/2 1 2 Miles



SOIL SURVEY MAP OF FULTON COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

NORTH EAST SHEET

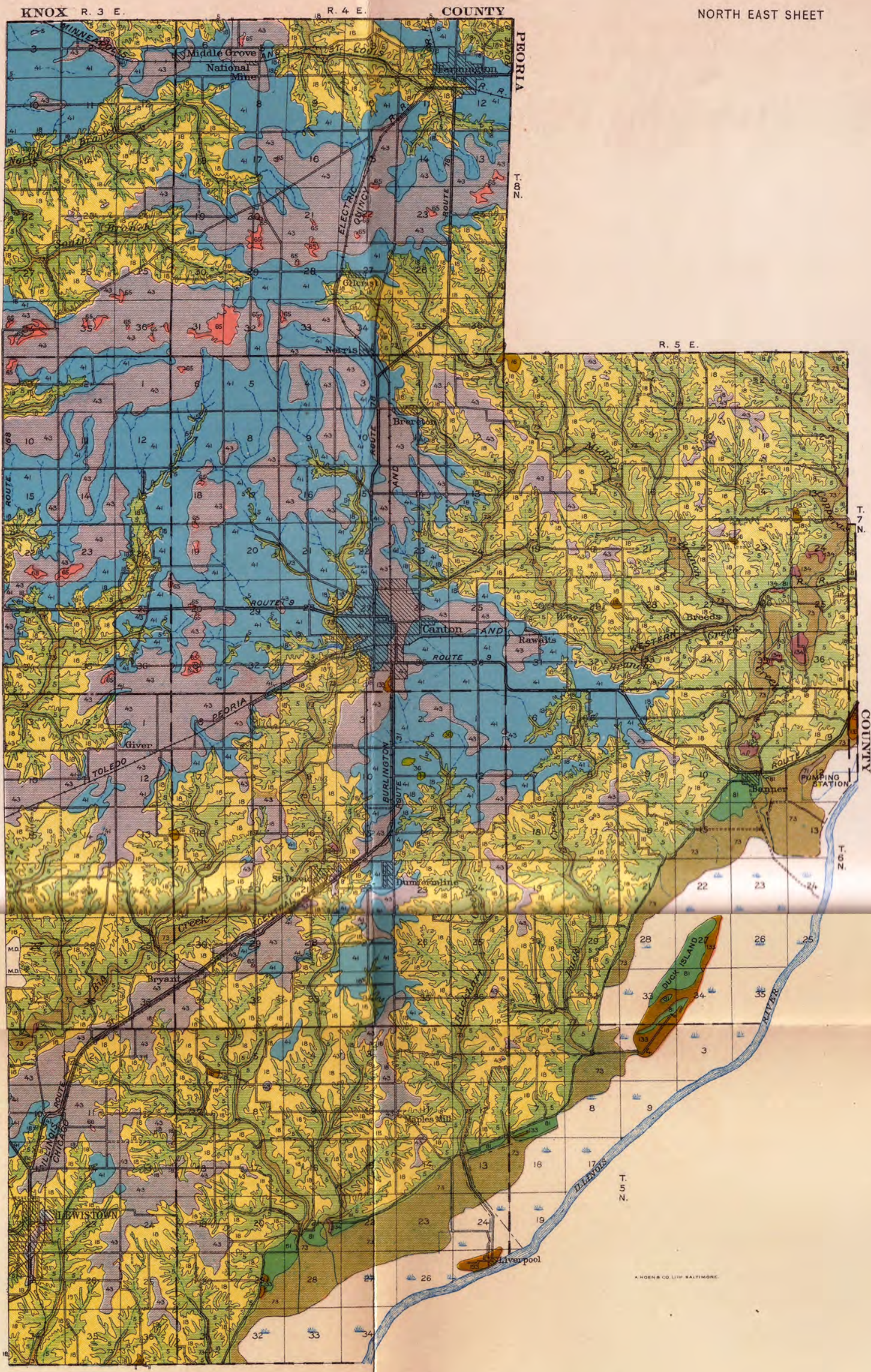
LEGEND

- 5 Eroded Silt Loam
- 16 Brownish Yellow-Gray Silt Loam On Tight Clay
- 18 Brownish Yellow-Gray Silt Loam
- 36 Light Brown Silt Loam
- 41 Brown Silt Loam
- 43 Brown Silt Loam On Clay
- 65 Black Clay Loam
- 66 Black Clay Loam On Drab Clay
- 71 Drab Clay
- 73 Brown Mixed Loam
- 81 Brown Silt Loam Over Sand or Gravel
- 133 Brown Sandy Loam Over Sand or Gravel
- 134 Brownish Yellow-Gray Silt Loam Over Sand or Gravel
- 136 Brown-Gray Silt Loam On Tight Clay Over Sand or Gravel

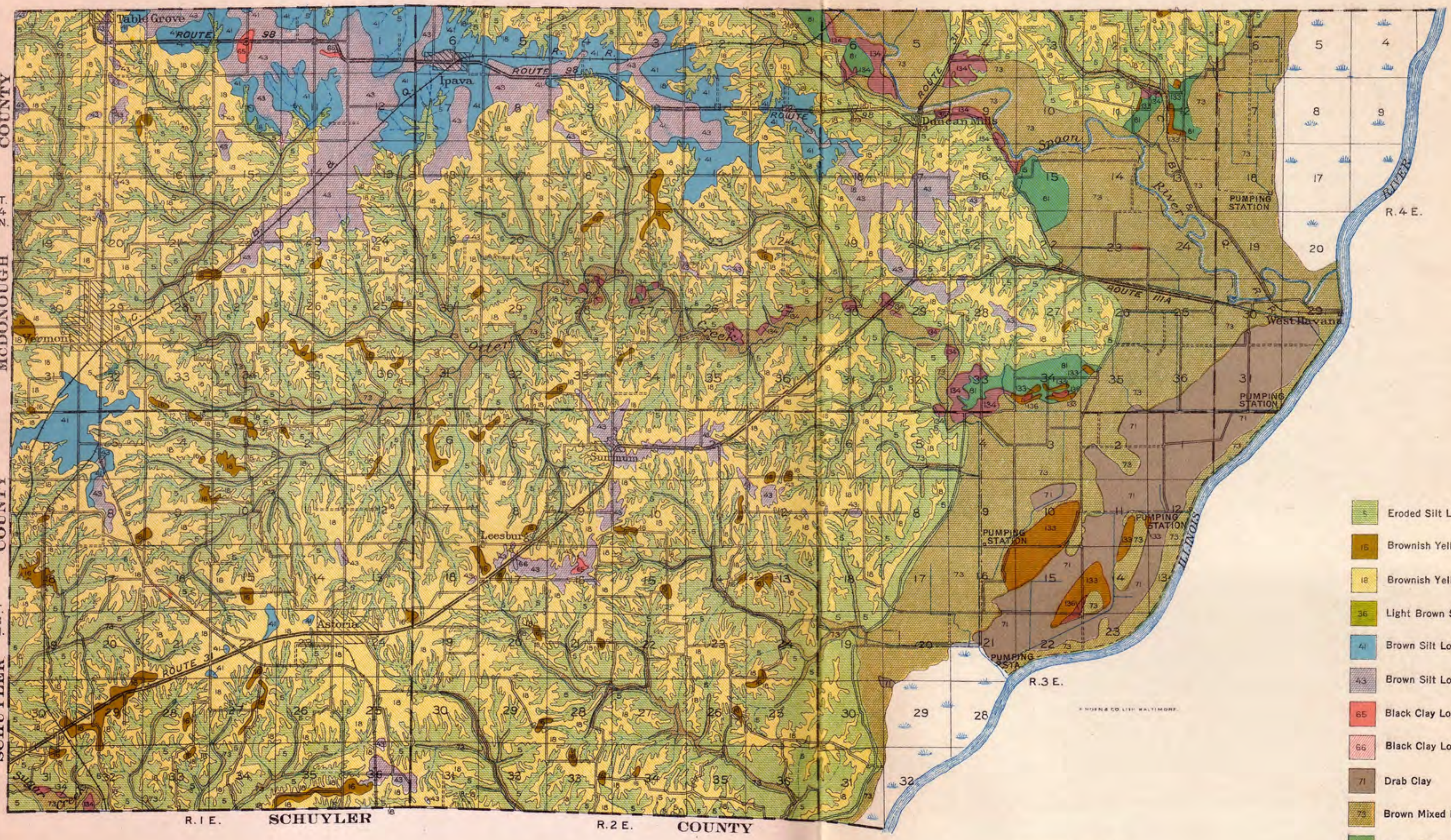
CONVENTIONAL SIGNS

- Public Roads
- Metalled Roads (gravel—all year)
- Paved Roads
- Private Roads
- Railroads (steam)
- Railroads (electric)
- Township Boundary Lines
- County Boundary Lines
- Levees
- Streams (flowing)
- Streams (intermittent)
- Lakes or Ponds
- Swamps
- Small Areas Limestone Rock Outcrop
- M.D. Mine Dumps

Scale
0 ¼ ½ 1 2 Miles



SOIL SURVEY MAP OF FULTON COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION



SOIL SURVEY MAP OF FULTON COUNTY
UNIVERSITY OF ILLINOIS AGRICULTURAL EXPERIMENT STATION

Scale 0 ¼ ½ 1 2 Miles

LEGEND

- 5 Eroded Silt Loam
- 15 Brownish Yellow-Gray Silt Loam On Tight Clay
- 18 Brownish Yellow-Gray Silt Loam
- 36 Light Brown Silt Loam
- 41 Brown Silt Loam
- 43 Brown Silt Loam On Clay
- 65 Black Clay Loam
- 66 Black Clay Loam On Drab Clay
- 71 Drab Clay
- 73 Brown Mixed Loam
- 81 Brown Silt Loam Over Sand or Gravel
- 133 Brown Sandy Loam Over Sand or Gravel
- 134 Brownish Yellow-Gray Silt Loam Over Sand or Gravel
- 136 Brown-Gray Silt Loam On Tight Clay Over Sand or Gravel

CONVENTIONAL SIGNS

- Public Roads
- Metalled Roads (gravel—all year)
- Paved Roads
- Private Roads
- Railroads (steam)
- Railroads (electric)
- Township Boundary Lines
- County Boundary Lines
- Levees
- Streams (flowing)
- Streams (intermittent)
- Lakes or Ponds
- Swamps
- Small Areas Limestone Rock Outcrop
- M.D. Mine Dumps